

Improving DoD Logistics

Perspectives from RAND Research

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Commission on Roles & Missions of
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PREFACE

Demands for many types of DoD materiel are highly variable, and the DoD lacks the capability to predict them reliably, particularly in wartime and over long horizons. As a result, RAND research on improving DoD materiel logistics has shifted emphasis over the past decade from developing improved tools for forecasting demands and allocating resources to redesigning logistics processes so that they can rapidly respond to shifting demands before the availability of weapon systems degrades. This perspective has been combined with reviews of innovative business practices in the private sector, practices that have resulted in customer-oriented approaches for improving DoD logistics processes with an eye to flexibility and responsiveness.

Over the same period, many in the DoD have concluded that DoD logistics should be reformed. In this documented briefing, we summarize the results of RAND's logistics research and discuss its implications for reforming DoD logistics. We describe a conceptual framework for developing and implementing reform efforts that emphasizes two roles for DoD logistics management in achieving improved process performance. First, all levels of management must work to improve logistics providers by establishing critical success factors, and by eliminating inhibitors and alleviating constraints to high performance. Second, high-level DoD managers, while aiding and monitoring these improvement efforts, must work to identify more-efficient and -effective governance structures for providing DoD logistics. These efforts are not mutually exclusive; rather, they reinforce each other and, together, form the framework necessary to ensure the effective and efficient provision of support to U.S. military operations now and in the future.

This documented briefing builds on RAND research in logistics undertaken for sponsors in the United States Army, Air Force, and Navy, and in the Office of the Secretary of Defense and the Joint Chiefs of Staff. It should be of interest to policymakers and managers in the DoD who are charged with responsibility for logistics reform.

The work was undertaken at the request of the Commission on Roles and Missions of the Armed Forces, which sponsored the research. The Commission was created in 1993 by Congress to review and evaluate "current allocations among the Armed Forces of roles, missions, and functions" and to "make recommendations for changes in the current definition and distribution of those roles, missions, and functions" (National Defense Authorization Act for FY 1994, *Conference Report*, p. 198). This response to the Commission's request is part of a larger effort by RAND to provide analytic support to the Commission's deliberations. The Commission does not necessarily endorse the options presented, the methodology involved, or the discussion contained in this documented briefing. This represents one of many inputs provided to inform the deliberations of the Commissioners, who applied their own experience and judgment in arriving at the conclusions and recommendations that are found in the Commission's final report, *Directions for Defense*. The work was conducted in RAND's National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, and the defense agencies.

The views expressed here are those of the authors and do not necessarily reflect the opinions or policies of the sponsors.

SUMMARY

This documented briefing presents a framework for developing strategies to improve the performance of DoD logistics processes. Such strategies will ensure that support to U.S. military operations is provided effectively and efficiently. Our framework emphasizes *managing DoD logistics processes* and *providers for high performance*:

- *Managing* refers to management activities--goal setting, performance measurement, resource allocation and budget execution, and planning and requirements estimation, etc.--at all levels in DoD logistics, from the shop floor to the highest levels of OSD.
- *Logistics processes* are the key operational processes of materiel logistics--procurement, distribution, and repair.
- *Logistics providers* are organizations that provide logistics products or services. These include organizations at all echelons of support and in both public and private sectors.
- *High performance* refers to superlative functioning, which has multiple dimensions, including aspects both of effectiveness and of efficiency.

In developing the framework, we drew on RAND research in logistics undertaken for sponsors in the United States Army, Air Force, and Navy, and in the Office of the Secretary of Defense (OSD) and the Joint Chiefs of Staff (JCS), as well as on recent literature on innovative business practices.

THE PERFORMANCE OF DOD LOGISTICS PROCESSES MUST IMPROVE

Demands for many types of logistics services and materiel in the DoD are uncertain. For example, removal rates for high-technology weapon system components vary widely and are difficult to forecast, even in peacetime. In contingency operations these demand uncertainties are exacerbated by many factors, including sudden changes in operational tempo, surge in demand volume, change in environment and urgency, and the wide spectrum of missions.

DoD's current logistics processes generally do not possess the desired characteristics for achieving effective and efficient support for uncertain demands. As a result, most of DoD's logistics processes perform poorly relative to both comparable processes in the private

sector and DoD's own performance standards. For example, data from the Logistics Intelligence File indicate that the distribution process--both in peacetime and in contingencies--is very slow and highly variable, whether judged by current commercial practice or by DoD's own relatively undemanding standards. Other data indicate that the procurement and repair processes are also too slow and variable. Variability in process performance is of special concern because it leads the customer to distrust the process and encourages coping actions and work-arounds that waste resources and further deteriorate process performance.

To cope with uncertain demands, the DoD has traditionally relied on a "mass-logistics" paradigm (so called because of parallels with the mass-production paradigm). This paradigm has emphasized three mechanisms for providing logistics support: (1) functional bureaucracies that result in numerous handoffs across organizational boundaries to execute processes, (2) large inventories, and (3) special management actions, such as expediting high-priority requisitions and intensively managing resources (e.g., numerous financial and administrative reviews). These mechanisms are inefficient, often ineffective, and not well-suited to provide the responsiveness and flexibility required in future military logistics operations.

**HIGH PERFORMANCE CAN BE ACHIEVED THROUGH PROCESS IMPROVEMENT, AS
COMMERCIAL FIRMS HAVE DEMONSTRATED**

Numerous analyses have highlighted the payoffs of redesigning logistics processes to improve their capability to respond quickly to uncertain demands. Highly responsive processes can be as effective as or more effective than today's processes. And remarkably, by shifting away from the mass-logistics paradigm, they can be less costly as well. When logistics processes are not responsive, large quantities of materiel remain in process (logistics "pipelines") rather than in use and do not contribute to weapon system availability. A more responsive logistics system would require considerably less inventory and associated infrastructure and personnel (e.g., warehouses, supply personnel, inventory managers) to sustain the same weapon system availability. When non-value-adding activities have been eliminated,

the redesigned processes are simpler, quicker, less prone to error, and less costly and labor-intensive to operate.

Many firms in the private sector have demonstrated that the performance of today's logistics processes can be improved along multiple dimensions, including response times, costs, flexibility, and quality. For example, private-sector firms have achieved dramatically lower response times in each of DoD's key logistics processes (procurement, distribution, and repair).

These firms have shown that process improvement is the key to achieving high performance. In some cases, the processes had to be redesigned ("reengineered"), and new technologies (relating both to processes and to information management) played a large role in enabling an improved process design. Some firms have implemented these process improvements internally; others have accessed improved processes by outsourcing to high-performing commercial providers of logistics services.

Through similar strategies, the DoD can reasonably expect dramatic, sometimes order-of-magnitude, performance improvements in its logistics processes. Whereas order-and-ship times and repair-cycle times are currently reported in weeks and months, they should be reported in days. Procurement times should be reported in weeks or days, particularly for commercially available items, rather than in months or years.

THE DOD HAS BEGUN TO IMPLEMENT PROCESS IMPROVEMENTS

Although DoD logistics has not kept up with the performance revolution that has transformed private-sector logistics, recent policy statements from top-level logistics managers in OSD recognize the need to move to more-responsive logistics processes. Moreover, numerous DoD organizations have initiatives under way to improve the performance of their logistics processes. Such initiatives include the Air Force's Lean Logistics and the Army's Velocity Management. Many of these initiatives--14 at the Defense Logistics Agency alone--have been designated as reinvention laboratories within the Defense Performance Review (DoD's efforts in the National Performance Review).

Initiatives to improve organic logistics processes (provided by DoD organizations) have the advantages that they can be undertaken immediately and are applicable to all of DoD's current logistics providers, albeit with varying potential for success. As a result, process improvement "in place" is particularly appropriate as a shorter-term approach. Unfortunately, DoD operations providing logistics services currently face legal, financial, and mission obstacles that may make it difficult for them to match best commercial practices. For example, achieving improved performance often requires up-front capital to invest in new technology and a flexible labor force, both of which may be more tightly constrained for the DoD organizations.

In addition to improving logistics processes provided by DoD organizations, the DoD, like some private firms, is seeking to outsource logistics services to high-performing providers in the private sector. Outsourcing is an attractive alternative to process improvement in place when high-performing private-sector providers are readily available. However, the DoD must address the numerous impediments to extending its use of outsourcing, including regulations on the selection of providers, high transaction costs, limited ability to enter into long-term partnerships, and limitations of existing contracting capabilities and vehicles.

Current and planned process-improvement and outsourcing initiatives represent significant efforts to improve the performance of DoD's key logistics processes. A few DoD logistics providers have already demonstrated that dramatic performance improvements similar to those achieved in the private sector can be achieved by the DoD.

STRATEGIES FOR IMPROVING DOD LOGISTICS MUST BE DEVELOPED AND IMPLEMENTED

To what extent the numerous initiatives to improve DoD logistics will be successfully implemented and what performance gains will result are not clear. A complicating factor is that aspects of DoD logistics management contribute to the difficulties of bridging the performance gap between military and commercial logistics.

First, the structure of DoD logistics--with multiple layers of management wherein top managers are far removed from the operation of key processes--has prevented the widespread and rapid dissemination of

the innovative methods being used in the private sector to achieve improved performance.

Second, management processes, policies, and regulations of DoD logistics do not provide the environment, incentives, and measures needed to engender high performance in either organic or private-sector providers. DoD management places emphasis at all levels, and particularly at the highest levels, on resource allocation and budget execution. Emphasis on process performance has been lacking. Indeed, the DoD has not even established performance standards for some critical segments of its key logistics processes; where standards are established, data indicate they are not being met. The lack of standards and of performance feedback "protects" providers that are underperforming.

To guide process-improvement efforts, DoD must shift to dynamic, performance-based management of its logistics system. This management approach requires three steps:

- *Establish clear goals.* This step entails defining a vision of high performance and quantifying the vision with metrics and associated performance standards that reflect best current practice.
- *Collect information to support decisionmaking.* Information is collected primarily to measure the performance of logistics processes and to compare that performance with standards and performance leaders inside and outside DoD. A second purpose is to identify, diagnose, and fix process breakdowns so that they do not recur. A third purpose is to determine when to periodically revise standards upwards.
- *Guide selection and enable implementation of initiatives.* DoD logistics managers can choose initiatives from two broad categories: those to improve processes of existing providers or those to outsource to high-performing providers. Making sound choices requires analyses that consider standards, performance measurements, diagnoses of performance deficits, estimated magnitude and timing of expected benefits and costs, associated risks, and likelihood of successful implementation.

Changes in governance (e.g., policies, regulations, ownership, and organizational structures) may help DoD to shift to dynamic, performance-based management of its logistics processes. For example, reorganization of management structures may contribute to implementing and establishing a more dynamic, performance-based management process.

Reorganization that flattens management hierarchies and aligns high-level management along the key logistics processes (e.g., repair, distribution, and procurement) can help improve management's focus on end-to-end logistics process performance.

DoD may also want to use an independent, outside advisory board (e.g., a Defense Logistics Board similar to the Defense Science Board) for assessing the overall performance of DoD's logistics processes and high-level DoD logistics management.

CONCLUSION

The DoD urgently needs from its logistics processes both cost savings and improvements in multiple dimensions of effectiveness and efficiency. Fortunately, the current downsizing environment provides DoD with an important opportunity to promote process improvement, much as global competition has driven the private sector to process improvement. However, improving processes throughout the DoD logistics system, both public and private, is a vast undertaking, on the scale of transitioning an entire industry--with multiple tiers of suppliers and interrelated processes--to a new paradigm. Achieving the desired savings and performance improvements will require from DoD's logistics managers both a fundamental shift in management emphasis and a sustained, highly focused effort to implement needed changes.

ACKNOWLEDGMENTS

This documented briefing draws on a long history of RAND logistics research, some of which is cited in footnotes and the bibliography. Although the final product remains the responsibility of the authors, we would particularly like to thank our RAND colleagues Frank Camm, Irv Cohen, David Chu, John Dumond, John Folkeson, Chris Hanks, Ray Pyles, Kenneth Reynolds, LTG (Ret.) Vincent Russo, and Jerry Sollinger for their insightful reviews of earlier drafts. We would also like to thank Jan Harris for her help in preparing the manuscript. Marian Branch's thoughtful, thorough editing greatly improved the exposition.

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ACRONYMS

AFMC	(U.S.) Air Force Materiel Command
AMC	(U.S.) Army Materiel Command
ATLASS	Asset Tracking and Logistics Supply System
CCP	Consolidation and containerization point
CIM	Corporate Information Management
CONUS	Continental United States
CRP	Central Receiving Point
DBOF	Defense Business Operations Fund
DDCO	Defense Distribution Depot, Columbus
DLA	Defense Logistics Agency
DTS	Defense Transportation System
DVD	Direct Vendor Delivery
DWASP	A data-processing system
EDI	Electronic data interchange
FMC	Fully Mission Capable
GAO	General Accounting Office
GOCO	Government-Owned, Contractor-Operated
GPRA	Government Performance and Results Act of 1993
GS	Government Service
ICP	Inventory Control Point
JCS	Joint Chiefs of Staff
LIF	Logistics Intelligence File
LRU	Line Replaceable Unit
MRO	Materiel Release Order
NICP	National Inventory Control Point
OCONUS	Outside the Continental United States
ODS	Operations Desert Shield/Storm
OMB	Office of Management and Budget
OOTW	Operations other than war
OSD	Office of the Secretary of Defense
OST	Order-and-ship time
POD	Point of debarkation
POE	Port of embarkation

PPBS	Planning, Programming, and Budgeting System
R&M	Reliability and Maintainability
SES	Senior Executive Service
SFDLR	Stock Funding of Depot-Level Reparables
SOP	Standard operating procedures
SRU	Shop Replaceable Unit
UMIMPS	Uniform Military Issue and Movement Priority System
USTRANSCOM	U.S. Transportation Command
VM	Velocity Management

Managing DoD Logistics Processes and Providers for High Performance

INTRODUCTION

In this documented briefing, we build on RAND research in logistics undertaken for sponsors in the United States Army, Air Force, and Navy, and in the Office of the Secretary of Defense (OSD) and the Joint Chiefs of Staff (JCS) to present a framework for developing strategies to improve the performance of DoD logistics processes. Such strategies are being developed to ensure that support to U.S. military operations is provided effectively and efficiently. The framework emphasizes managing DoD logistics processes and providers for high performance.

We begin with some definitions. First, by *managing* we are referring to management activities at all levels in DoD logistics, from the shop floor to the highest levels of OSD. Management activities can be grouped into key processes, such as goal setting, performance measurement, resource allocation and budget execution, and planning and requirements estimation. In this document, we emphasize two roles for management in process improvement. The first role is creating an environment within the existing governance arrangements that is conducive to process improvement. Such an environment is created by providing critical success factors (e.g., incentives and resources), eliminating inhibitors, and alleviating constraints to process

improvement. The second role, specific to higher levels of management, is changing the existing governance arrangements within DoD to provide greater access to or allow the development of higher-performing logistics providers.

By *logistics processes*, we mean the key operational processes of materiel logistics¹--procurement, distribution, and repair--which are fundamental to providing logistics services. Because the logistics processes we define are very broad, they are often distributed across different logistics providers.

By *logistics providers*, we mean organizations that provide products or services associated with segments of the logistics processes. DoD logistics providers include both the wholesale and installation or theater levels (i.e., all echelons of support) and both the public and private sectors. Used at one level, the term *logistics providers* can refer to very large organizations, such as the Defense Logistics Agency (DLA) or the Army Materiel Command (AMC). Logistics providers can also refer to smaller entities, e.g., specific DLA distribution depots or even a specific shop within an AMC maintenance depot.

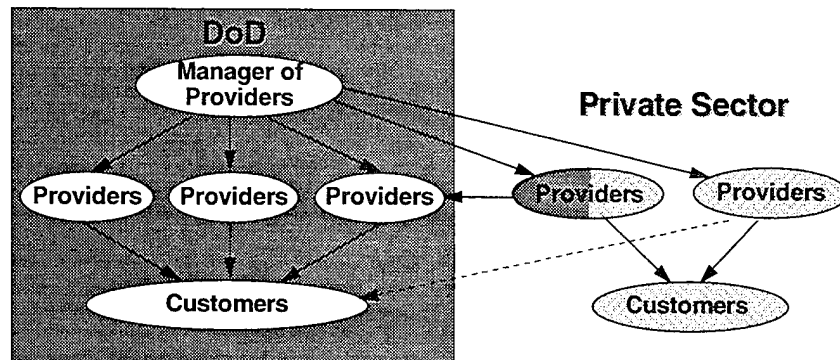
By *high performance*, we refer to multiple dimensions of superlative functioning, including aspects both of effectiveness and efficiency. The DoD needs effective logistics processes that are responsive (i.e., fast and reliable), high quality, robust (flexible), and adaptive (innovative) in both deployed and nondeployed operations. DoD's logistics processes must also be efficient, because only processes that utilize resources very productively are likely to be affordable. Key to obtaining high performance is establishing high, mission-appropriate standards and measuring progress relative to those standards along the multiple dimensions of performance.

The remainder of this section provides a brief overview of DoD materiel logistics.

¹ By many definitions, *logistics* is much broader than materiel logistics. For brevity, the term *logistics* will be used here to refer to materiel logistics.

DoD Is a Manager, Provider, and Customer of Logistics

DoD Logistics



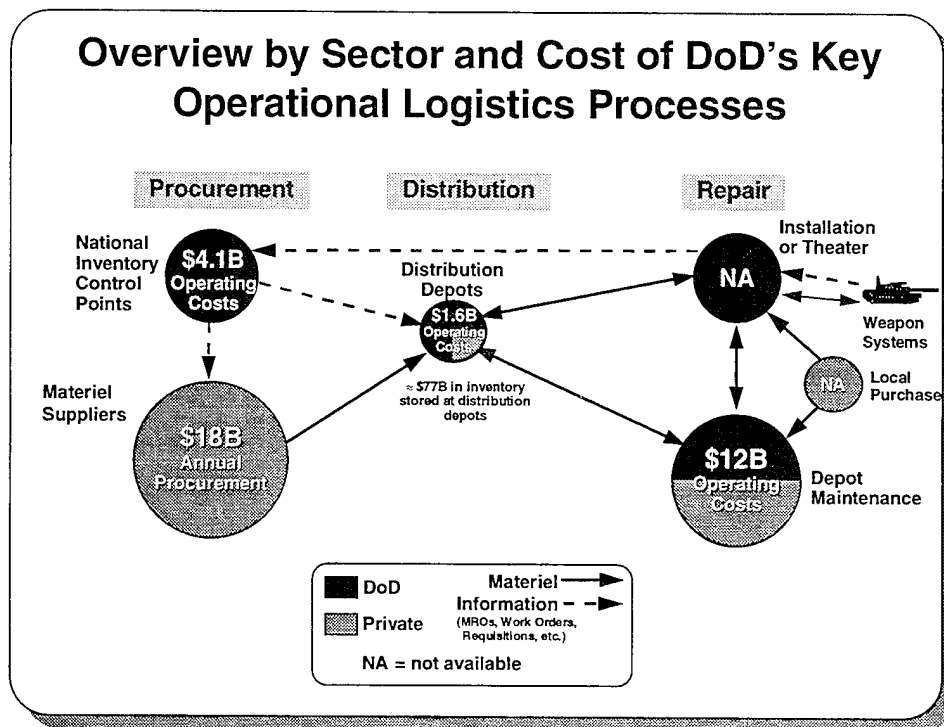
This chart presents an aggregate-level view of DoD logistics. While some of DoD's logistics providers (darker shading) are in the private sector, DoD organizations manage all logistics providers, provide logistics services, and are the end customers. The involvement of DoD organizations in all three roles differentiates the market for DoD logistics from that in the private sector.² Lacking the incentives provided by profit motive and market competition, DoD's logistics managers face special challenges in achieving and maintaining high performance in their logistics processes.

For simplicity, the chart differentiates the three roles. At the highest levels of OSD and the service staffs, logistics managers have the role of establishing efficient governance arrangements for providing access to and management of the logistics providers who carry out DoD's logistics processes. These managers have broad responsibilities and

² Similar arrangements may exist at some levels of private-sector supply chains. For example, General Motors (GM) headquarters and central purchasing manage all of GM's providers, some of which include GM-owned parts manufacturers (e.g., Delco Electronics). These GM-owned parts manufacturers provide products to customers that are also GM-owned organizations (e.g., the Chevrolet division of GM). However, the ultimate end customer in private-sector supply chains is generally not a member of the organization.

establish policies across the logistics processes, but they rely on managers closer to the operational processes to implement those policies.

At other levels, all three roles can occur in a single organization. For example, the commander of a distribution depot manages private-sector organizations that provide the depot with transportation services (manager of provider role, although some aspects of this activity are often centralized to a single agency), provides distribution services such as pick, pack, and ship to customers (provider role), and is a customer of deliveries made by vendors and arranged by a National Inventory Control Point (customer role). The depot commander's range of responsibility across the distribution process is limited; nonetheless, the depot commander can have an immediate effect on the depot's processes and providers.



Whereas the preceding chart focused on the different roles in DoD logistics, this chart represents the aggregate-level costs of providers of products and services associated with DoD's three key logistics processes--procurement, distribution, and repair.³ The chart is arranged in approximate columns according to process and indicates by sector (public or private) where the majority of the operating costs occur.⁴

The circles, which represent activities, are sized in proportion to their annual operating costs, where available, for fiscal year 1994.⁵

³ Other supporting functions or subprocesses to procurement, distribution, and repair (e.g., establishing stock levels and maintaining parts catalogues) are included in the dollar totals.

⁴ The chart significantly simplifies how DoD and private-sector providers map into the three key logistics processes. For example, National Inventory Control Points (NICPs), shown only in the far left under the procurement process, also play a role in both (depot) repair and distribution processes. As another example, although only the distribution depots are shown under the distribution process in the above chart, both ordering and shipping of materiel in the distribution process include the installation or theater and maintenance depots.

⁵ The dollar figures for operating costs were taken from Office of the Secretary of Defense (1993). Procurement costs also were estimated from that reference, using the cost of materiel sold from inventory and assuming a replacement policy of 65 cents for each dollar. As will be discussed below, reliable cost data for DoD logistics are problematic.

Operating costs represent just one dimension of performance related to efficiency and are highlighted just to give the reader a sense of the size of DoD logistics. Other dimensions of performance are discussed in greater detail in the next section.

Distinctions are made between the costs associated with DoD and those associated with private-sector providers. While not depicted in the chart, the annual operating costs of activities associated with DoD could be further divided into the responsible service or defense agency (e.g., Air Force, Army, DLA, Navy, and Marines) and eventually down to individual providers (e.g., a specific distribution depot).

A large portion of the annual costs of DoD logistics is for the purchase of materiel from the private sector. However, DoD organizations account for the vast majority of the annual operating costs for logistics services at the installation or theater level. And, at the wholesale level, the majority of the non-manufacturing logistics services are also provided by DoD organizations; the primary exceptions are second-destination transportation (depicted in the distribution depot operating costs) and about 49 percent⁶ of the depot-level repair (depicted in the depot maintenance operating costs).⁷ Hence, for DoD logistics to achieve high performance under the *current* governance arrangements, DoD organizations that operate important segments of the key logistics processes must achieve high performance.

The logistics processes of procurement, distribution, and repair have strong interrelationships. For example, the quality, cost, and responsiveness of a repair shop are in part a function of how well the shop's demands for spare parts are supported by the distribution process. If parts support is poor (slow and highly variable), the repair shop risks repairs being halted for lack of spare parts. As a result, the repair shop must maintain large inventories of spares (tying up capital and even requiring additional supply personnel) to keep mechanics working. As another example, if the procurement process is long and variable, owing to either administrative or production lead

⁶ Depot-level repair is the percentage of estimated work years of depot maintenance and repair performed by contractors (Office of the Secretary of Defense, Economic Security [1995]).

⁷ Some percentage of the annual operating costs associated with DoD organizations also makes its way into the private sector (e.g., local purchase of parts and services, for which data are not available). However, at the wholesale level, the largest category of costs for logistics services provided by DoD organizations is labor, representing almost \$7B of the \$11B (Office of the Secretary of Defense [1993]).

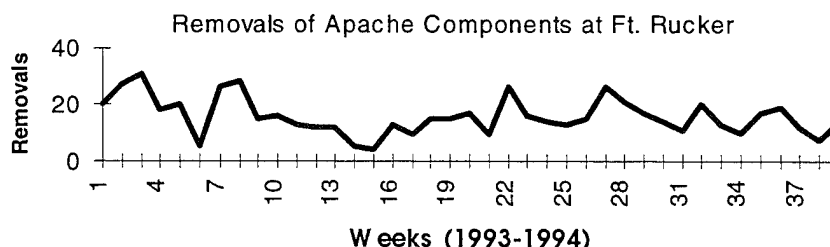
times, the distribution depots must maintain larger inventories of materiel to protect against back orders. (Back orders occur when the requested materiel is not in stock at a DoD distribution depot and may dramatically increase response times to the customers of the distribution depot, such as the repair shop in the previous example.) Hence, achieving high performance in one process will not be possible without complementary improvements in the other two processes.

Outline

- *DoD logistics processes must improve along multiple dimensions of performance*
- Implementation of process improvement has led to high performance in the private sector
- Process-improvement efforts are ongoing in DoD logistics
- Strategies for improving DoD logistics must be developed and implemented

In this section, we summarize (1) RAND research demonstrating that the DoD's materiel logistics processes face very uncertain demands, (2) analyses suggesting that the process improvements needed to effectively support uncertain demands are feasible and can also result in reduced costs, and (3) empirical data showing that the current response times of many DoD logistics processes are slow and highly variable--characteristics that are not desirable for reacting effectively and efficiently to uncertain demands.

Demands on DoD Logistics Processes Are Uncertain



- **Highly variable demands (even in peacetime)**
- **High variability is exacerbated during deployments**

Empirical data show that demands for many types of logistics services and materiel in the DoD are uncertain.⁸ For example, removal rates for high-technology weapon system components vary widely over time and other factors and, hence, are difficult to forecast even in peacetime.⁹ The chart above depicts removals of the night-vision and targeting system components for 45 Apache attack helicopters stationed at Fort Rucker, Alabama.¹⁰ It is but one example of the uncertain

⁸ A large body of RAND research documents the difficulty of forecasting demands in both peacetime and contingencies. References include Brown (1956), Crawford (1988), Hodges and Pyles (1990), Cohen et al. (1991), Robbins et al. (1991), Pyles and Shulman (1995), and Adams et al. (1993). In particular, Crawford (1988) investigated the effect of different aggregations of demands and showed that large variability persisted. For corroborative research, see Slay and Sherbrooke (1988).

⁹ Improvements in processes upstream from the logistics support system can be used to reduce the burden on DoD's logistics processes. RAND research (Gebman et al. [1989] and Dumond et al. [1994a]) has documented the benefits of a process called *maturation development* for reducing the demands on logistics processes. However, even with reduced overall logistics burden, the problem of uncertainty remains.

¹⁰ Variable flying hours do not account for the high variation in the removals, because flying rates were relatively constant over this period. Nor is this a question of aggregation of demands. As in Crawford (1988), unpublished RAND research on this data also shows that

demands faced by DoD logistics processes, even in installation-based (or peacetime) operations.

During contingency operations (including both wartime and operations other than war [OOTW]), the uncertainties faced by DoD logistics processes are exacerbated by a combination of factors, including sudden changes in operational tempo, changes in environment and urgency, and the wide spectrum of missions. The result is that demands for materiel and services are even harder to forecast.¹¹

These uncertain demands resemble the logistics challenges faced by many private-sector organizations,¹² which have long cited unreliable forecasts as a problem.¹³ But military logistics processes experience more-extreme surges in demands (greater uncertainty) and have more at stake when they fail to meet those demands. The extensive body of research on demand uncertainty led RAND to the conclusion that inventories (with their heavy reliance on accurate forecasts) were being overemphasized as a buffer for the uncertain demands associated with military operations. Rather, *logistics processes* that can react, adapt, and recover before the availability of weapon systems degrades are also essential for *effective support*.

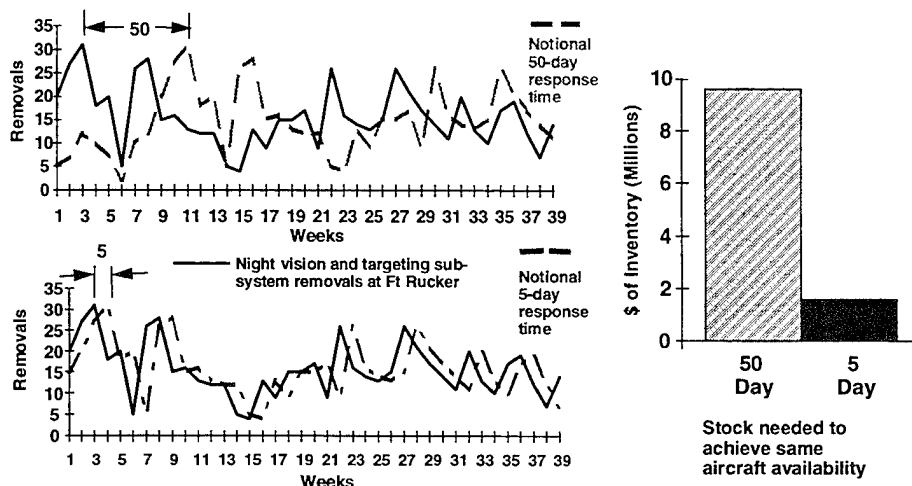
different aggregations of demands (across bases) still result in highly variable demands.

¹¹ Pyles and Shulman (1995).

¹² For a description of the effect of a change in demand on a manufacturing and distribution system, see Senge (1990); in particular, see Chapter 3, "Prisoners of the System or Prisoners of Our Own Thinking?"

¹³ Stalk (1988), p. 46.

Responsive Logistics Processes Reduce the Need for Inventories



Numerous analyses have been carried out to provide evidence of the payoffs of focusing on improving the ability of logistics processes to quickly react to, adapt to, and recover from uncertain demands in both peacetime and wartime.¹⁴ The chart above depicts a simple analysis demonstrating the advantages of a more responsive support process for the demands depicted in the preceding chart. In this case, the support process encompasses all activities required to identify and remove a faulty part, to move the unserviceable part to the appropriate level of maintenance, to repair the part, and then to move the part back to the weapon system or supply for reissue. Overlaid on the actual demand data are two notional support processes, one an order of magnitude faster than the other (5 days versus 50¹⁵ days).

¹⁴ References include Berman et al. (1981), Cohen et al. (unpublished draft), Robbins and McIver (1994), Robbins et al. (1991), and Cohen et al. (1991), all of which deal primarily with spare parts (generally high-cost reparables). Girardini et al. (unpublished draft) apply the concepts to ammunition distribution; their application suggests the manner in which a responsive logistics paradigm might be applied to heavy and bulky commodities.

¹⁵ Repair times for night-vision and targeting system components from one Army post in 1993-1994 averaged 45 days, with a standard deviation of 50 days. Other component wholesale repair times can be as long as a year due to slow, non-serviceable retrograde and long-term

Such markedly different response times are indeed possible. The majority of the time in the support process requiring 50 days would be spent in non-value-adding activities, such as batching the turn-in of unserviceable parts (due to the low priority accorded to the turn-in of unserviceable parts), turning unserviceable parts into supply rather than maintenance (creating two extra handoffs), batching information (as a result of outdated information systems), holding parts for transport (to minimize transportation costs), and queuing or batching parts for repair. In the support process with 5-day response time, many of the sources of the above delays would be identified and eliminated by simplifying the process in order to eliminate handoffs; reducing batching by moving to smaller, more frequent deliveries of materiel and information; and identifying and alleviating bottlenecks to reduce queuing. Value-adding activities (e.g., requisitioning, packaging) would also be continuously improved.¹⁶

These two notional support processes are charted against the same highly variable demand in the line charts on the left. The more responsive process more closely follows the highly variable demands--that is, the more responsive process reacts to and recovers more rapidly from the uncertain demands.

The bar chart at the right illustrates that the more responsive process also has considerably lower inventory costs¹⁷ to maintain the same weapon system availability.¹⁸ Furthermore, operating costs can also decrease (not depicted in the bar chart). For example, whereas some operating costs can increase (e.g., increased use of premium transportation and increased repair capacity that results in lower

scheduling of repair. Thus, 50 days is not unreasonable for current wholesale repair times. Note also that the end item, the Apache helicopter, may be repaired quickly using a serviceable component. The times in the chart are for the repair of the component.

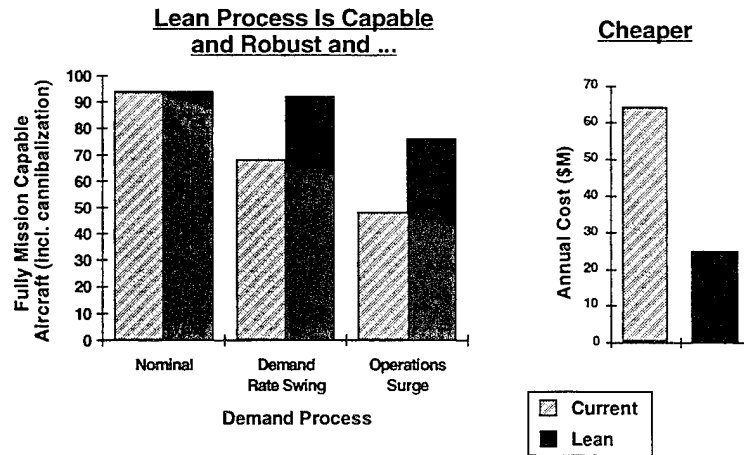
¹⁶ Robbins (unpublished draft) documents the histories of specific maintenance work orders, identifying where problems with parts availability (as well as other factors) delayed repairs.

¹⁷ This example actually understates the inventory reductions of a more responsive process. In the chart above, the less responsive support process always takes exactly 50 days. However, as is shown later in this section, DoD's logistics processes also exhibit a high degree of variability. (Generally, high variability, as well as slow response, is characteristic of processes with multiple handoffs, infrequent batching of information and materiel, and extensive queuing.) Hence, if the 50-day process also had high variability, even larger inventories would be required to buffer the system against supply, as well as demand, uncertainty.

¹⁸ At an average cost of about \$100,000 each for these components, such a reduction systemwide could result in substantial savings.

utilization rates and reduced queuing delays), the elimination of labor-consuming non-value-adding activities often results in a more responsive process that is simpler and, hence, less costly to operate (even without accounting for inventory savings). As a variation on this analysis, the same inventory levels could be assumed for both processes, resulting in the more responsive process achieving a higher level of weapon system availability.

Lean Logistics Process Provides Improved Robustness at Lower Costs



The above chart¹⁹ shows a more sophisticated analysis than that in the preceding chart, using RAND's Dyna-METRIC²⁰ model to assess the performance of different processes for supporting 1,200 non-engine F-16C reparable components whose demand rates are related to flying hours. A force of 474 F-16C aircraft, located at 10 bases (ranging in size from 12 to 72 aircraft) and flying a program of 1.2 flying hours per day per aircraft, was examined in the analysis. Comparisons were made between current and lean processes for supporting the 1,200 reparable components. The "lean" process emphasizes changes required to provide effective wartime support by eliminating non-value-adding activities (e.g., batching and holding of materiel and information) and by simplifying the process overall, which reduces the need for both complex management schemes (such as setting priorities, and figuring out work-arounds and lateral resupplies) and complex information systems.²¹

¹⁹ Obtained from our RAND colleague Ray Pyles and to be published in a forthcoming Project AIR FORCE report on "Lean Logistics."

²⁰ For an overview of Dyna-METRIC's capabilities, see Isaacson et al. (1988).

²¹ Cohen et al. (unpublished draft) provide a detailed description of the lean process, which includes repair and return (to expedite delivery of unserviceable parts directly to the maintenance shop) and overnight delivery.

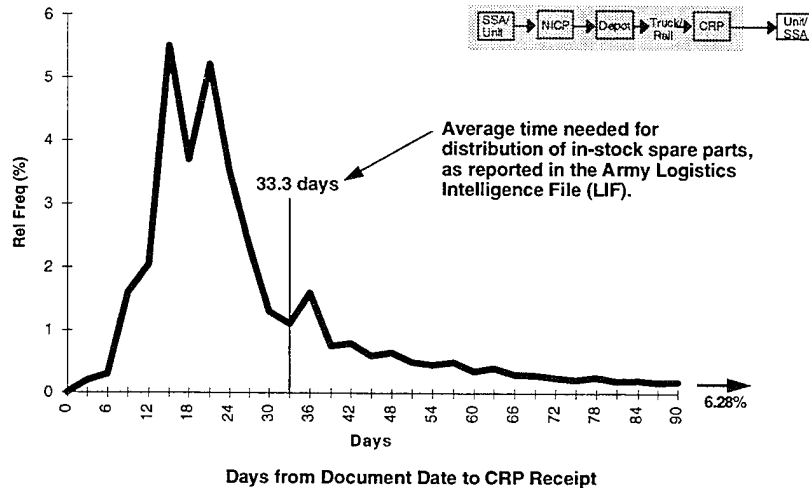
For the planned peacetime flying program, stocks at different levels were provided to both the current and lean processes so that their performance would be approximately equal (85 percent aircraft availability without cannibalization and over 90 percent with cannibalization). The first two "nominal" bars on the left show that performance is the same for the planned scenario. The logistics-planning assumptions were then changed. In the second set of bars, stock levels computed for 1989 demand rates were used against 1991 demand rates to demonstrate robustness against year-to-year variations in demand rates (i.e., the effects of peacetime, or nondeployed uncertainty). In the third set of bars, half the force was flown at Desert Storm flying rates (approximately 5 times peacetime rates). As the bars indicate for the F-16C, the lean process was more robust (i.e., it kept more aircraft Fully Mission Capable) than the current process.

The bar chart on the far right shows that the lean process also costs one-third as much to operate. In this bar chart, both inventory and operating costs are included. While some operating costs increased (e.g., transportation), much leaner inventories and simplified management resulted in significantly lower overall operating costs.

Some readers may be surprised that simplified and more-responsive processes can simultaneously be as effective or more effective and less costly. The explanation for this counterintuitive result lies in the costs of non-value-adding or underutilized resources. Costs for DoD logistics processes take the form of materiel (dominated by inventory) and services (a large component of which is labor). If logistics processes are not responsive, then investments are needed in large quantities of materiel that are "in process" (referred to as "pipelines" in logistics) rather than in use and do not contribute to weapon system availability. These seemingly one-time investments in inventory can lead to recurring higher materiel costs as a result of obsolescence, excesses, and materiel that is purchased new instead of repaired. Furthermore, processes are often slowed by labor-consuming activities that add limited value or can be done more efficiently (e.g., multiple handoffs and administrative checks, work-arounds to expedite processing, and personnel to manage large inventories required to buffer slow processes). Hence, a closer look suggests that the seeming paradox is not a paradox at all--a critical point, given the pressure to reduce spending on DoD logistics without "hollowing out" the force.

Because RAND was motivated to perform these analyses by the desire to help the DoD achieve effective support under highly uncertain demands, the large inventories needed to buffer uncertain demands made the cost-versus-benefit trade-off more striking (i.e., it is possible to achieve large reductions in pipelines). The results of this and similar analyses led RAND to seek approaches that de-emphasized resource-intensive methods of responding to uncertain demands, such as large inventories of stock, and put increased emphasis on process improvements. Simplified processes are more robust against the uncertainties of deployed operations and dramatically reduce procurement times, order-and-ship time (OSTs), and repair-cycle times.

Performance of the Distribution Process for CONUS Requisitions Is Too Slow and Variable



RAND's emphasis on process-oriented research resulted in the collection of empirical data from various services' data files to measure the performance of DoD's logistics processes and to further reinforce the case that more-responsive logistics processes were needed. The empirical data supported anecdotal evidence that DoD's logistics processes generally did not possess the desired characteristics for achieving effective and efficient support for uncertain demands. For example, the chart above²² depicts the responsiveness of the wholesale distribution process²³ measured from the date of an Army requisition (in the continental United States [CONUS]) to reception at the

²² Moore et al. (unpublished draft).

²³ Because many orders are filled from local (retail) stocks and repair sources, the chart above does not represent how long it takes to fill every Army requisition. In fact, many of the requisitions on the wholesale system are to replenish local inventories. However, even for replenishment requisitions, the slow and variable order-and-ship time depicted in the chart increases both the required size of local inventories and the chances that local inventories will be out of stock, which can create future readiness problems and reduce sustainability (e.g., units may have to deploy without all their assigned stocks).

installation's Central Receiving Point (CRP).²⁴ Days are plotted on the horizontal axis; the vertical axis plots the percentage of all requisitions that were received by the CRP on the *n*th day. The data are for requisitions of spare parts (class IX) with all back orders removed (i.e., the requisitioned parts were "on the shelf" at a DoD distribution warehouse in CONUS). The data come from the Army's Logistics Intelligence File and include all requisition priorities for the period June 1, 1991, through May 31, 1992.

These data suggest that the distribution process in peacetime is not only slow but also highly variable.²⁵ Hence, in addition to having to adjust to very uncertain demand patterns, the customer (e.g., a mechanic or local supply clerk) must also cope with supply uncertainty.²⁶ This supply uncertainty leads the customer to distrust the process and encourages rational coping actions--such as duplicating requisitions, hoarding parts, and cannibalizing parts off of other weapon systems--that can further deteriorate process performance.

Because of the interrelationships of different logistics processes, variability can take on additional importance. For example, many parts may have to be ordered and received before a repair can be completed. The greater the number of parts ordered, the higher the odds are that one of the requisitioned parts will be in the tail of the above distribution, which will hamper the ability to complete the repair.²⁷

Similar charts can be constructed showing that the procurement and repair processes, like the distribution process, are also slow and highly variable in peacetime (although response times are more item-specific than is the case with the distribution process).

²⁴ Because most Army installations operate their own internal distribution processes (a segment of the overall distribution process), the data depicted above do not represent final delivery to the customer. Hence, times for wholesale distribution to the final customer (the person who requisitioned the parts) would be longer.

²⁵ Given that the graph includes different-priority requisitions, we would expect to see some variability. However, analysis of the responsiveness for requisitions of like priority reveals similar variability, although the means are different. Girardini et al. (unpublished draft).

²⁶ To the customer, variability in the operational processes is another source of uncertainty (we have already discussed the inherent uncertainty in the demands) that must be dealt with in providing support (i.e., Will parts that are ordered arrive on day 5 or day 50, or on some other day?).

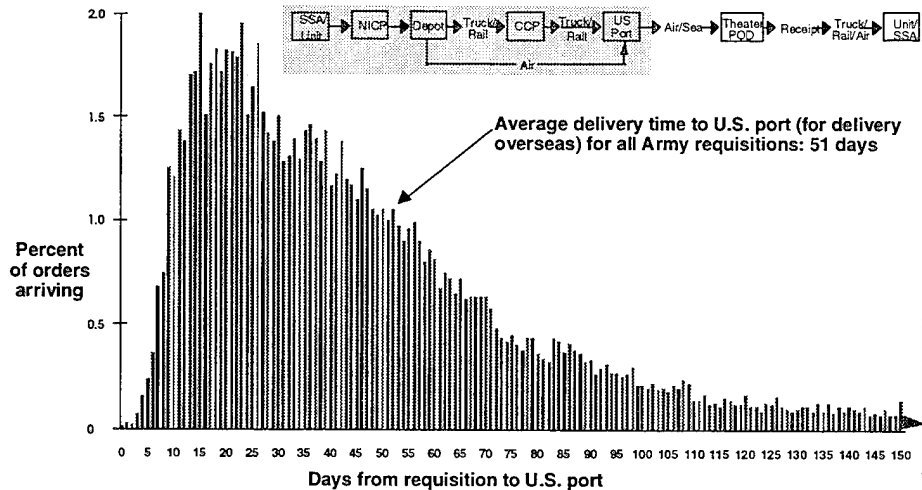
²⁷ Robbins (unpublished draft) documents the effect of variable OSTs on specific work orders.

Rather than focusing on processes that react, adapt, and recover more rapidly, DoD's traditional logistics paradigm (referred to as the *mass-logistics* paradigm because of parallels with the mass-production paradigm) has placed heavy emphasis on three mechanisms for providing logistics support: (1) *functional bureaucracies*, (2) *large inventories*, and (3) *special management actions*, such as expediting high-priority requisitions and intensively managing resources (e.g., carefully monitoring transportation). Although they have served in the past, these mechanisms are inefficient, often ineffective, and not particularly well-suited to provide the responsiveness and flexibility required of future military logistics operations, for the following reasons:

- Functional support bureaucracies are well-suited for vertical command and control and planning but deal poorly with constant change, uncertainty, and beginning-to-end process performance because they require numerous handoffs across organizational boundaries to execute business processes. Functional support bureaucracies also tend to become inflexible, unresponsive, inwardly focused, and difficult to coordinate horizontally.
- Reliance on inventory assumes that underlying average demand rates are stable in peacetime and predictable in wartime--neither of which is true, as extensive research at RAND and elsewhere has shown.
- Special management actions usually involve human intervention, extra controls, and work-arounds--which tend to increase manpower needs, can be rapidly overwhelmed by surges in demands, and can actually add to response times rather than shortening them.

The next chart offers an example of the ineffectiveness of this paradigm.

Recent Deployments Further Highlight Poor Process Performance



Recent deployments (ODS, Restore Hope, etc.) have further highlighted the poor performance of DoD logistics processes and the ineffectiveness of the mass-logistics paradigm for providing robustness against wartime surges in demands. The chart above depicts the responsiveness of the distribution process measured from the date materiel was requisitioned in-theater to the date it was received at the CONUS air- or sea port for movement overseas during Operation Desert Storm (ODS).²⁸ The chart excludes transit time overseas, clearing the port in-theater, and in-theater distribution. Each of those segments requires additional time (e.g., 15 to 20 days for transit by sealift) and is an additional source of variability. Data limitations precluded estimating these latter segments of the distribution process.

Again, days are plotted on the horizontal axis; the vertical axis plots the percentage of all requisitions that were receipted at the CONUS port on the *n*th day. The data include materiel from all classes of supply for the period May 1, 1990, through June 30, 1991. Back orders are excluded (i.e., materiel was in a DoD distribution warehouse somewhere in CONUS).

²⁸ A sample of 600,000 ODS requisitions with valid entries in the appropriate fields of the Army Logistics Intelligence File.

The slow and highly variable²⁹ responsiveness of the distribution process is again evident and, in fact, is degraded from the peacetime performance (previous chart) as a result of the additional challenges of ODS.³⁰ These additional challenges included greatly increased volume, capacity imbalances across processes (e.g., CONUS distribution capacities far exceeded capacities in-theater, particularly in the initial stages of the deployment), severe competition for strategic lift, and a more dynamic environment in which plans and priorities rapidly changed and units frequently moved.

As in the previous chart showing response times in peacetime, measurements of the response time of the distribution process in a major regional contingency (MRC) support the assertion that the existing process is unable to react and adapt to uncertain demands, suggesting that the process is not robust. Under the principles of the mass-logistics paradigm, large inventories of materiel were intended to provide robustness against wartime surges in demand. Instead, because the distribution process took so long to move the materiel to deployed units, those large inventories often ended up in long pipelines and, hence, did not contribute to combat capability in-theater. As in peacetime, highly variable response times resulted in rational coping actions by customers (e.g., reordering items to ensure delivery), which further degraded the performance of the distribution process.

In addition, the labor-intensive special management actions associated with the mass-logistics paradigm and used to reallocate, expedite, and otherwise "work around" the routine distribution process,

²⁹ The data are for various classes of materiel (primarily IX and II) and all priorities, so some variability in the overall distribution is to be expected. However, when requisitions for like materiel and priority were isolated, similar variability in response time was observed, although the means were different.

³⁰ This does not imply that, in specific cases for some process segments, rapid response times were not achieved. A special Desert Express air channel was established for moving critical materiel to Saudi Arabia. Also, anecdotal evidence suggests that response times for some segments of the procurement and repair processes were reduced in ODS, implying better response times are possible in these processes. Those improvements were often the result of eliminating steps that are not normally challenged under less-urgent circumstances. For example, repair times for wheels and brakes on landing gear at Ogden Air Logistics Center, Utah, were reduced from 30 to 10 days, on average (Grier [1992]). Procurement times were reduced to rapidly equip units with Global Positioning System receivers (Sweeney [1993]), and in the deployments to Somalia, special procurements rapidly provided units with pepper spray (discussions with personnel from the Army's Armament, Munitions, and Chemical Command).

were rapidly overwhelmed by the surge in high-priority demands. Similar degradation has been observed in smaller contingencies.³¹

As in peacetime, the long response time associated with the distribution process was primarily a result of queues and "batch delays" (i.e., running a program that processes requisitions once a day, resulting in significant delays for many requisitions) in each segment of the process. Only a small percentage of the time represents activities, such as the transfer of information (e.g., requisitions) and the picking, packing, and moving of materiel, that are required to provide the materiel to the customer.

In summary, empirical data from the services suggest that DoD's logistics processes do not have the characteristics that analysis indicates are necessary to sustain effective and efficient operational support in the face of uncertain demands in either nondeployed or deployed operations.

³¹ See Robbins (unpublished briefing) for discussions of Operations Restore Hope (Somalia) and Just Cause (Panama).

Outline

- DoD logistics processes must improve along multiple dimensions of performance
- *Implementation of process improvement has led to high performance in the private sector*
- Process-improvement efforts are ongoing in DoD logistics
- Strategies for improving DoD logistics must be developed and implemented

In this section, we discuss research reviewing innovative management practices in the private sector, where, as the discussion of Lean Logistics in the preceding section suggested was possible, process performance has been improved along multiple dimensions. Most of the following examples reflect a fundamental shift from the principles associated with mass production and mass logistics. As a result, there are now significant differences in response time between the better private-sector firms and DoD for similar logistics processes.³²

Contributing to this performance gap are two factors related to DoD logistics management. First, the *structure* of DoD logistics has presented an obstacle to widespread and rapid dissemination of the methods being used in the private sector to achieve improved performance. Second, management *processes, policies, and regulations* of DoD logistics are not providing the right environment, incentives, and measures to engender high performance in either internal (organic) or external (commercial) providers.

³² Performance gaps of similar magnitude were documented between mass and lean producers in the 1980s (Womack et al. [1990]).

Process Improvement Has Been the Basis of the Revolution in Business

FIRM	Response -Time Reduction	Increased Productivity	Inventory Reduction	\$ Savings	Process
Schlumberger Oil Field Sensors ³³	83% (Product Lead Time)	38%	60%	NA	Job Shop (Repair)
Detroit Diesel ³⁴	NA	NA	83%	NA	Repair
Cummins Diesel Service Parts Division ³⁵	NA	NA	87%	\$151M	Distribution
Montgomery Ward ³⁶	NA	38%	50%	NA	Distribution
Portland General Electric ³⁷	97% (Lead Time)	89%	NA	NA	Procurement
Texas Instruments ³⁸	75% (Lead Time)	75%	NA	\$30M/yr	Procurement

NA= not available

Whether as a result of the quality movement or the current emphasis on process reengineering, it is clear that process improvement is the key to achieving high performance along multiple dimensions. The chart above reports improvements for selected commercial firms that have implemented improvements in processes similar to DoD's key logistics processes. In some of the above examples (and others in the literature), the processes had to be redesigned ("reengineered"), and new technologies (relating both to processes and to information management) played a large role in enabling an improved process design.

For example, in 1989, Texas Instrument's Defense Systems and Electronics Group had an 18-step procurement process that averaged 16 days and required manual entries, reviews, and much paper. It then increased the use of electronic data interchange (EDI) to transmit purchase orders to suppliers. It also extended EDI back through its own procurement process to simplify and automate the movement of information

³³ Aston and Cook (1989).

³⁴ Dumond et al. (1994a).

³⁵ Dumond et al. (1994a).

³⁶ Canna (1989).

³⁷ Davenport and Short (1990), p. 19.

³⁸ Weissenborn (1992).

from the requisitioner of the materiel to the buyer, finance, and accounting. It also reduced the number of suppliers. The result was a paperless 3-step process that averages 4 days and saves \$30M/year (Weissenborn, 1992).

In other efforts, processes or segments of processes were outsourced to providers with higher performance (i.e., who had already established efficient and effective logistics processes). Specific examples include National Semiconductor, which partnered with Federal Express; Sun Express, which contracted out parts distribution to Caterpillar Logistics Services;³⁹ and Dell Computers, which outsourced its shipping to Roadway Logistics Systems. A whole new industry of third-party or contract logistics has emerged that provides logistics services to others.

Whether through internal process-improvement efforts or outsourcing to third-party logistics providers, these efforts began with a customer focus. They identified and eliminated activities that did not add value for the customer and improved those that did. These efforts also represent a shift away from the principles of mass logistics. The results have been improvements across multiple dimensions, including response time and costs (in which reductions in inventory and direct and indirect labor are often reported as proxies for cost savings).

³⁹ A year after Sun Express outsourced its warehouse operations and parts distribution to Caterpillar Logistics Systems, its costs for these activities as a percentage of revenue were halved. It also was able to quickly expand operations into Europe (two months) and Japan (three months).

DoD Has Not Kept Up with the Revolution in Commercial Logistics

Process	DoD ⁴⁰	Commercial Companies ⁴¹		
Distribution (for in-stock items)	26 days ⁴²	1 day ⁴³ Motorola	3 days Boeing	2 days Caterpillar
Repair (cycle time)	40-144 days (DoD average)	3 days Compaq	14 days Boeing (electronics)	14 days Detroit Diesel
Repair (shop time)	8-35 days (Army tank/truck)	1 day Compaq	10 days Boeing (electronics)	5 days Detroit Diesel
Procurement (administrative lead time)	88 days (DLA)	4 days Texas Inst.	0.5 days Portland General	

Overall, DoD logistics has not kept up with the revolution that has occurred (and continues to occur) in commercial logistics.⁴⁴ Successful

⁴⁰ The references for DoD response times are (moving top to bottom): DLA Logistics Response Measurement File (3/95); IBES Inc., *Pipeline Management: The Next Step*; Department of the Army, Office of the Deputy Chief of Staff for Logistics; and DLA Procurement (2/95).

⁴¹ The references for commercial companies' response times are (top to bottom and then left to right): Dr. William H. Davidson, "Beyond Reengineering: The Phases of Business Transformation," presentation to the Council of Logistics Management Annual Conference, Cincinnati, OH (10/94); Compaq laptop repair program; Compaq laptop repair program; Weissenborn (1992), p. 176; 2/95 conversation with Boeing Commercial Airplane Group; 2/95 conversation with Boeing Commercial Airplane Group; 2/95 conversation with Boeing Commercial Airplane Group; Moore et al. (unpublished draft); 2/95 phone conversation with Detroit Diesel Remanufacturing West; 2/95 phone conversation with Detroit Diesel Remanufacturing West; Davenport and Short (1990), p. 19.

⁴² Average time from requisition to receipt acknowledgment for all items DLA manages, all priorities of requisitions (high and routine), and all customers (domestic and overseas). The average time from order receipt by DLA (National Inventory Control Point) to shipment by DLA depot is 4 days for high priorities and 7 days for routines.

⁴³ For custom pagers--includes manufacture of the product as well as distribution.

⁴⁴ For a good overview of what we have called the *revolution in business*, see Levine and Luck (1994). Bowersox et al. (1989) report on

private-sector firms are much further along in shifting away from the mass-logistics paradigm and have achieved dramatically lower response times in each of DoD's key logistics processes (procurement, distribution, and repair).⁴⁵ Despite the difficulties of comparing response times across different processes,⁴⁶ the gaps in response times listed in the table are compelling and costly to DoD in both effectiveness (readiness and sustainability) and efficiency.

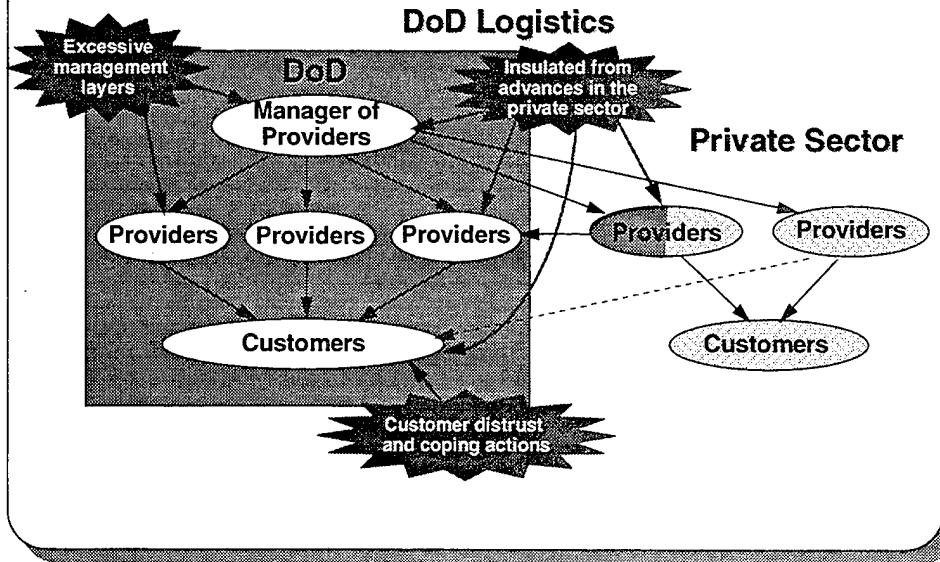
The DoD currently has legal, financial, and mission restrictions that may make it difficult, if not impossible, for it to match best commercial practices in its logistics processes. For example, achieving improved performance often requires up-front capital to invest in new technology and a flexible labor force, both of which may be more tightly constrained for the DoD. Also, DoD must retain capabilities for wartime surges that create slack (in materiel, labor, or capacity) in logistics processes, making it more difficult to introduce the daily stresses that lead to incentives for continuous improvement. However, one of the key messages of this document is that much more can be done within current constraints, and, where constraints are binding, DoD logistics management must work to expeditiously identify them and implement solutions.

common characteristics of successful North American logistics organizations.

⁴⁵ Similar gaps along multiple dimensions of performance have been documented in the shift from mass to lean production and product development (Womack et al. [1990] and Garvin [1983]).

⁴⁶ Comparisons of data on process performance, even for a simple measure such as response time, can be fraught with difficulties. Differences in scope and scale, different ways of defining and measuring process performance, and availability of like services for similar materiel are just some of the complicating factors.

Structure of DoD Logistics Has Impeded a Shift Away from Mass Logistics



To close the performance gap between better logistics providers in the commercial sector and providers in the DoD, it is important that knowledge about the process-improvement revolution that is taking place in the commercial sector be widely disseminated. Furthermore, the general principles of process improvement must be understood and accepted by managers, operators, and customers. However, as the above chart⁴⁷ depicts, several factors have impeded this process from occurring expeditiously in DoD logistics.⁴⁸

One impediment is the multiple roles played by DoD organizations in DoD logistics. DoD organizations are the manager of providers, the provider, and the customer of DoD logistics, which reduces the interaction with high-performing commercial logistics providers. Furthermore, while a large percentage of the products and services in DoD logistics is supplied by private-sector providers, those providers

⁴⁷ The above figure is an aggregate-level (simplified to one echelon of providers; actually multiple echelons exist) view of the multiple roles played by DoD--manager of providers, owner of providers, and customer--and the relationships between them.

⁴⁸ Similar impediments to the adoption or adaptation of new business practices and their implementation have been observed in industries within the private sector. See Womack et al. (1990) and Finegold et al. (1994).

can remain insulated from innovations in commercial logistics if DoD is their only or major customer. Where this is not the case, many private-sector providers have effectively partitioned their DoD and commercial operations (e.g., Motorola and Boeing). Such partitioning can occur as a result of the administrative difficulty of dealing with DoD or the difficulty of dealing with DoD's mass-paradigm mentality for purchasing products and services.⁴⁹ This latter reason is especially evident when the private-sector provider deals with a DoD provider rather than the DoD end customer.⁵⁰

As has occurred in many large, vertically integrated corporations, the mass-logistics paradigm, with its emphasis on functional bureaucracies, has led to multiple layers of management wherein top managers are far removed from operational processes.⁵¹ Where top management has operational experience, it is likely to be dated. Hence, process improvement can involve concepts that have been long removed from the focus of top managers. Also, the dependence of mass logistics on intensive management of large inventories and management-intensive work-arounds for satisfactory performance has led to management layers that have become self-perpetuating and resistant to change.

Moreover, customers have become accustomed to the poor performance associated with the mass-logistics paradigm. They have developed rational coping actions and work-arounds that have become embedded in local procedures and will be difficult to change. For example, they have come to rely on the large inventories required for acceptable support under the current long response times associated with DoD's logistics processes. And, despite the evidence from the private sector and numerous analyses, many in DoD logistics--and many of its

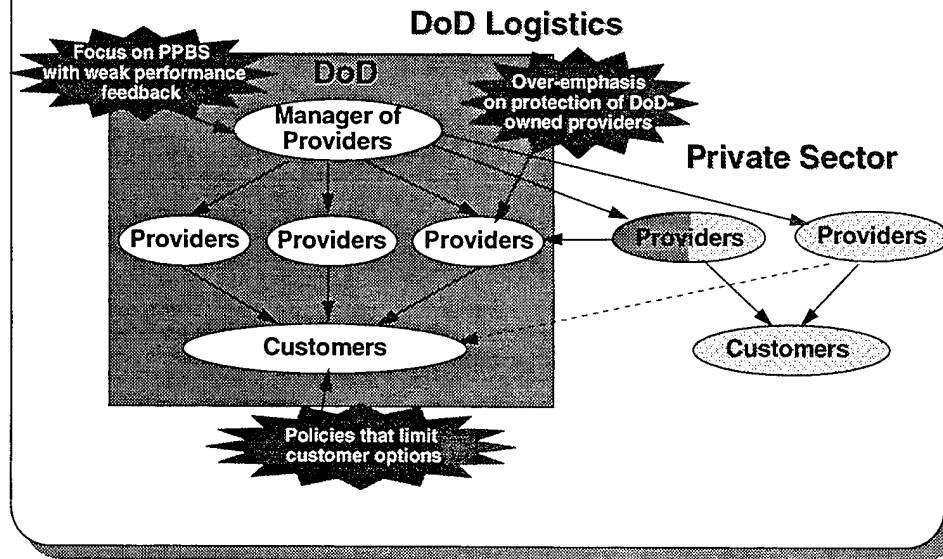
⁴⁹ When Boeing Commercial Airplane Group quotes a commercial customer, the cost is in dollars or pennies. When Boeing Aerospace quotes the U.S. government, it costs about \$600 (Commission on Roles and Missions of the Armed Forces Colloquium [1995]).

⁵⁰ For example, small-package delivery to an installation's Central Receiving Point, not the maintenance mechanic; delivery of parts from suppliers to DoD distribution depots, not directly to DoD customers; and depot-level maintenance contracted by DoD NICPs, not units or commands using the equipment.

⁵¹ "Another reason that government is one of the notable laggards in reengineering, politics aside, is that reengineering is about achieving operational excellence, and most government agency heads have very little experience with operations. They are primarily policy people; reengineering is often a real stretch for them" (Hammer and Champy, 1993, p. 222).

customers--will continue to place ultimate faith in the principles of mass logistics in deployed operations (e.g., the desire for self-sufficiency that commanders feel they can achieve only with large inventories suggests that many commanders will want "60 days" on the ground). Distrust of logistics processes runs deep, and current attitudes will not change easily. Much like the consumer who has been disappointed with a poor-quality product, DoD logistics customers will likely retain many doubts even after logistics processes have begun to improve.

Management Processes, Policies, and Regulations Also Have Impeded High Performance



Even if all of DoD's logistics managers, providers, and customers were knowledgeable about leading commercial logistics practices and committed to shifting away from mass logistics through process improvement, DoD logistics managers would still face a daunting challenge: establishing the management processes, policies, incentives, and regulations to change an industry as large and with as many stakeholders as DoD logistics. This challenge exists at all levels of logistics management, from the manager of a shop floor who must implement process improvement to the highest offices in OSD who must empower the shop manager and consider changes to existing governance arrangements. In the above chart we indicate how management processes, policies, and regulations impede high performance at each level. We discuss each impediment below.

FOCUS ON PPBS, WITH WEAK PERFORMANCE FEEDBACK

DoD management places emphasis at all levels, and particularly at the highest levels, on the Planning, Programming, and Budgeting System (PPBS) and budget execution. The cycle of requirements estimation, allocation of resources, and budget execution consumes vast management resources and, in some cases, has become cumbersome. It has spawned a

whole culture, organizational structure, and bureaucracy with natural incentives to perpetuate itself. At the same time, as indicated by the examples in the previous tabular chart, the performance of many logistics processes has been poor and has been considerably outperformed by similar processes in the commercial sector. This situation suggests that feedback (i.e., measuring and reporting) on process performance has been weak, and attempts to remedy performance problems have not worked to date.

This failure should not be surprising, given that financial considerations provide very strong incentives. However, as is typical of most nonmarket organizations, budgets for DoD organizations that provide logistics services have not been tied to performance criteria. DoD logistics managers have long been aware of the emphasis on PPBS and budget execution and of the fact that if budgeted funds were not spent, future budgets would likely be reduced--hardly the correct structure to provide incentives for implementing process improvement. The result has been weak feedback on the performance of logistics processes and a poor incentive structure for improving performance.

Another reason for the budget focus is that current financial and operational management systems are unable to measure or link such performance criteria as costs and response times to relevant parts of DoD's logistics processes.⁵² Rather, costs are aggregated to budget categories, not processes or functions, and functional performance measures are typically internally focused (e.g., fill rate at supply depots and utilization rate at maintenance depots) rather than customer focused (e.g., overall order-and-ship time experienced by the customer). Complicating this picture is the fact that it is not in the interest of the lower levels of logistics management to have accurate costs or other measures of performance if, as the previous chart suggests, there is reason to believe that their activities are significantly underperforming. Thus, we have a logistics performance "Catch 22": The information is not there to focus on logistics performance, and the likelihood of underperformance currently provides little incentive to expend the resources or time required to obtain accurate performance information.⁵³ Absent such information, budgets are the primary lever

⁵² "If you can't measure it, you can't manage it" (Tapscott and Caston, 1993, p. 77).

⁵³ This problem is not unique to the DoD or government. A number of leading logistics companies could not measure how their processes were performing. Many applied activity-based costing and installed new

that high-level logistics managers currently have to try to affect logistics performance.

A shift in management emphasis from PPBS and budget execution toward establishing strong feedback on process performance to expand the portfolio of levers available to DoD's logistics managers is necessary. However, the current budget focus results, in part, from OSD being evaluated by Congress to a large extent on budget and budget execution. Because OSD focuses on budgets (viewing budgets, along with policy mandates, as their only tools for implementing changes), lower layers of management that must respond to OSD queries focus on budget issues as well. To overcome the impediments of the existing management bureaucracies' lack of appropriate performance measures, any change in management emphasis will require a change in focus by the Congress, the Office of Management and Budget (OMB), and OSD to areas beyond budget accountability.

OVER-EMPHASIS ON PROTECTION OF DOD-OWNED PROVIDERS

Attempts to seek out alternatives to DoD-owned providers have often been limited by legislation, regulations, or local procedures.⁵⁴ Many of these limits are imposed on DoD by Congress, with the explicit or implicit intent to protect DoD providers and public-sector jobs.⁵⁵

The lack of performance evaluation in favor of an emphasis on resource allocation and budget execution "protects" DoD providers that are underperforming. Also, confusion results over DoD's multiple roles as manager of logistics providers (i.e., suppliers of services and products) and owner of logistics providers, making it difficult to evaluate the appropriate level of vertical integration in DoD logistics. For example, OSD and the services, even at levels (e.g., service staffs) where their primary role should be as managers of providers, have had a

information systems to better measure the performance of their processes (Pohlen and LaLonde [1994], pp. 1-23; Cooke (1994), pp. 64-66).

⁵⁴ For example, Congress has imposed limits on the percentage of depot repair that can be done in the private sector (i.e., no more than 40 percent of depot repair is to be performed by contractors). It is difficult at best to explain these specific limits in terms of such logistics performance measures as efficiency and effectiveness (e.g., responsiveness, quality, and robustness).

⁵⁵ Also, even regulations for choosing among non-DoD providers may emphasize criteria other than high performance (e.g., fairness and opportunity for government business) or may be interpreted locally as placing undue emphasis on a single dimension of performance (e.g., lowest cost).

tendency to hold resources centrally for the providers they own, reinforcing the sense of protection--sense of ownership--without a concomitant emphasis on performance evaluation. As well, DoD managers who should be managing providers have had a tendency to become involved in how operational processes run rather than in setting standards, monitoring performance, and sending the signals--indications of the directions in which providers should be moving--and providing incentives for improving.

Corporate Information Management (CIM) provides a good illustration of a major OSD initiative that encourages the tendency of high-level management both to hold resources centrally and to get involved directly in operational processes rather than sending signals and establishing incentives. The initial emphasis of OSD's CIM initiative was to reduce the costs incurred by DoD developing and fielding information systems--i.e., to consolidate information systems. To accomplish that goal, CIM is requiring the services and DoD line agencies (e.g., DLA) to standardize most data systems to one existing system across similar *functions* (e.g., supply management and warehousing), a massive, centralized undertaking. Unfortunately, owing to a history of procurement and development delays, some of the information systems now designated as the standards are outdated by commercial standards.

One of the most fundamental lessons learned in the private sector is that changes to information systems will yield only marginal improvements if they focus on improving information support to the current process ("paving cowpaths" or "automating the current manual process").⁵⁶ Rather, both improvement steps should occur in parallel: the process should be redesigned to take advantage of advances in information, communications, and other technology, then information systems should be developed or adapted to support the new process. Many of the process improvements DoD needs involve better aligning DoD's current logistics *functions* (e.g., warehousing, supply management) along *process* (e.g., distribution, repair, and procurement) lines. Hammer and Champy (1993), Davenport (1993), and Tapscott and Caston (1993) highlight the role of information technology in enabling radical process redesign and improvement. If, under CIM, information systems are not planned and designed in parallel with process improvement, they are

⁵⁶ The Texas Instruments' EDI example given earlier in this section illustrates the order-of-magnitude improvement possible by properly leveraging information technology.

likely to constrain or inhibit rather than enable and facilitate. Moreover, time spent waiting for the completion of this massive centralized undertaking will impede the implementation of process improvement for DoD-owned logistics providers.

POLICIES THAT LIMIT CUSTOMER OPTIONS

Because the customers are also members of DoD organizations, managers can establish policies that limit customer options. Such policies vary from local procedures requiring extensive paperwork for going outside the DoD system (e.g., local purchase) to budget-allocation schemes for DoD funds that effectively eliminate choices for the customer and place the choices with the providers.

By comparison with the CIM initiative, the Defense Business Operating Fund (DBOF)⁵⁷ represents an attempt to send the right signals and incentives with less *direct* intrusion on logistics processes by informing customers of the economic consequences of their choices. With the goal of creating a more businesslike environment, the DBOF consolidated the stock and industrial funds in DoD and changed how they were managed.⁵⁸ Unfortunately, for many DBOF services, DoD-owned logistics providers do not have the information or experience necessary to set prices in a marketlike way.⁵⁹ Further, price-setting mechanisms are tied to the cumbersome appropriation processes of both providers and customers. Thus, DoD-owned providers charge prices that are often far out of line with actual costs, particularly for intra-fund transfers between different DBOF business units, and with the costs of comparable service in the commercial sector.⁶⁰

⁵⁷ The DBOF is a revolving fund that is required by DoD financial-management policy to match revenue to expenses year to year. If expenses exceed revenues, DBOF activities must either reduce costs (i.e., reduce overhead and make process improvements) or increase prices. Current DBOF policy allows activities to increase prices to make up for losses when expenses exceed revenues. The GAO has noted that this practice inhibits the implementation of business improvement.

⁵⁸ For example, the Stock Funding of Depot-Level Reparables (SFDLR) changed depot-level reparables from being centrally funded free issues to being stock-funded items.

⁵⁹ Further, even when pricing data were available, the Joint Logistics Systems Command, a product of CIM, has not allowed the services to change their software to implement better pricing.

⁶⁰ For example, DLA distribution depots may charge the NICP (intra-fund transfer) the same fee to pick, pack, and ship an order consisting of a single battery as for an order filling several trucks. Or a DoD customer may get the same credit for an unserviceable spare part whether

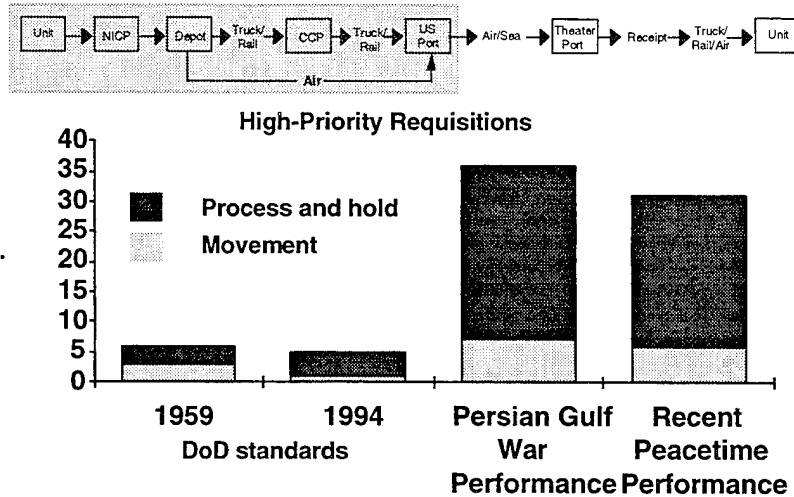
However, the DBOF has not created responsive mechanisms for reducing or increasing the services offered by DoD-owned providers based on customer choices. Where customers have no choices and there is no competition, the establishment of transfer prices, while providing more information to customers, does not of itself create the incentives necessary to implement process improvements. All these factors have undercut the incentives for providers to implement process improvement that have come from the creation of the DBOF and the establishment of SFDLR.⁶¹

By giving customers more choices and monitoring their choices, DoD managers can establish a feedback loop on the performance of providers. Monitoring which providers are preferred will provide strong indications of provider performance from the customers' perspective.

it has one failed circuit board or 10 failed circuit boards. At least three changes appear to be required in the current methods for establishing costs: (1) more-accurate pricing structures for provided services and management information systems to track more-accurate costs, (2) more-dynamic pricing to accurately reflect demands, and (3) better methods for allocating overhead, such as activity-based costing.

⁶¹ In fact, the current inflexibility to shift funds between organizations has actually inhibited some process improvements whereby the benefits occur outside of the organization incurring costs (e.g., DLA paying more for faster transportation that reduces inventory costs for its customers).

DoD Set Low Performance Standards and Failed to Meet Them



Empirical data on the distribution process from the Army's Logistics Intelligence File support the assertion that DoD logistics managers have not always sent the signals necessary to provide incentives for process improvement. In the chart above, the two leftmost bars represent the changes to DoD standards for high-priority requisitions for a segment of the distribution process (requisition to U.S. port) from 1959 to 1994. Over this 35-year span, in which an entire industry has emerged for overnight delivery of high-priority cargo, very little change has occurred in the DoD standard for high-priority requisitions.

Moreover, actual performance, as illustrated by the two rightmost bars, has rarely achieved even the low standards set by DoD. Furthermore, until recently, standards have been based on average performance, so exceeding the standard in any particular instance has not been viewed as a failure. By comparison, an organization such as Federal Express views every instance of exceeding its standard as a failure; hence, each employee knows when he or she is holding a package that has not met the standard.

The data in the chart suggest that DoD's logistics processes have operated with minimal performance feedback. Otherwise, measurements

would have identified where the process is breaking down and would focus management resources on improving performance.

Worse, DoD management has not even established standards for some critical segments of its key logistics processes. For example, there are no performance standards for the administrative process of moving from purchase request to purchase order, which is a critical segment of the procurement process. Slow and variable performance in procurement leaves DoD subject to a large number of back orders (i.e., requisitions for which there are no parts left on the shelf) or large stocks of materiel that lead to excesses (materiel that is no longer needed because demands changed during the long procurement process).

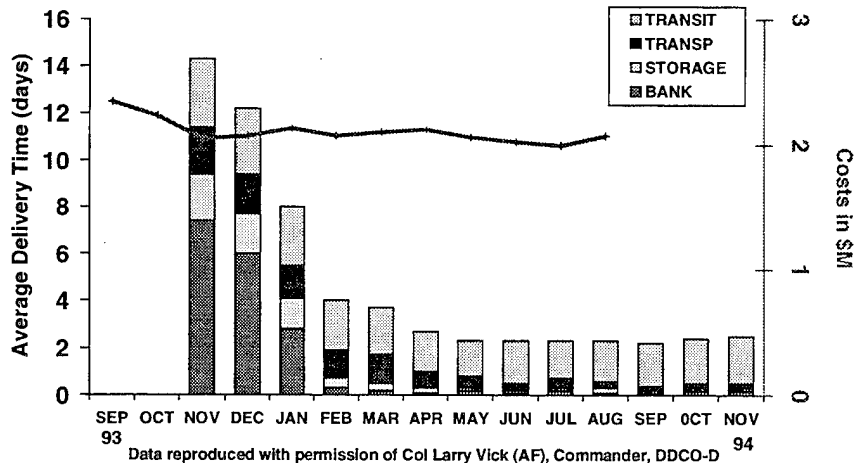
While DoD's overall logistics performance needs to improve and the growing performance gap with industry needs to shrink, all is not bleak. DoD has a number of logistics success stories and initiatives under way to improve logistics performance. We discuss those successes in the next section.

Outline

- DoD logistics processes must improve along multiple dimensions of performance
- Implementation of process improvement has led to high performance in the private sector
- *Process-improvement efforts are ongoing in DoD logistics*
- Strategies for improving DoD logistics must be developed and implemented

In the last section, we focused on the performance gap between leading commercial companies and DoD logistics. In this section, we focus on efforts by DoD's logistics managers and providers to close the gap. First, we provide a few examples of how implementation of process improvement by DoD logistics providers has resulted in dramatic reductions in response times in relatively short time frames. Second, we review some recent management signals in the right direction. Lastly, we discuss the potential benefits to DoD of improving its logistics performance.

Columbus Distribution Depot Has Demonstrated Dramatic Improvements in Response Times



Some DoD logistics providers have demonstrated that process improvements similar to those achieved in the private sector can be achieved by the DoD. For example, the Defense Logistics Agency's Defense Distribution Depot, Columbus (DDCO), has made great strides in reducing its response time, as shown above. In November 1993, DDCO initiated process improvement by establishing measures of performance. DDCO determined that it was taking 14.3 days to handle Transportation Priority 3 orders (i.e., routine shipment) from receipt of a Materiel Release Order (MRO) from an Inventory Control Point to delivery to the customer (which, based on customer feedback and commercial standards, was too long).

The depot aimed to reduce cycle times and variation. It started by measuring and charting cycle times to see where time was being spent. Time was broken into four segments:

- Bank: receipt of MRO by DWASP (a data processing system) to release for depot processing
- Storage: release for depot processing to offer of release to carrier (includes print, select, pack, and offer)
- Transportation: offer of release to carrier to actual release

- Transit: release to carrier to receipt by installation, consolidation and containerization point (CCP), or port of embarkation (POE).

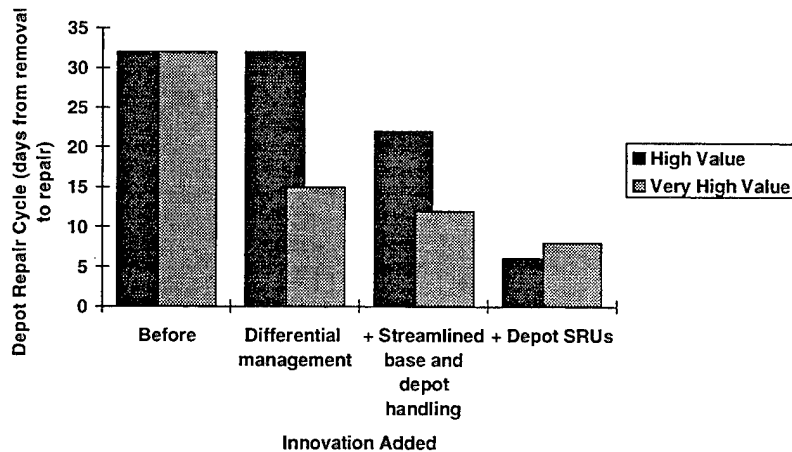
DDCO synchronized old batch information systems to shorten the time it takes to move information (MRO) needed to initiate the picking of parts from the warehouse. It also stopped banking (holding and thereby delaying customer orders) MROs to level workload and minimize transportation costs. To accommodate these changes, DDCO augmented personnel by expanding position descriptions and using GS volunteers. It staggered shifts and set time goals to meet transportation cutoffs. It offered shipments as early as possible, quickly moved materiel to transportation, and, where possible, "hot-loaded" trucks (i.e., reduced number of lifts by moving materiel directly onto the truck). It no longer held materiel for consolidation to another day, and it contracted carriers to pick up on weekends and late in the day. Lastly, it used dedicated trucks where possible (and responsive) and used small-parcel carriers for materiel up to 150 lb.

To attain its process improvement, DDCO used information, training, empowerment, and a union partnership, together with a change in culture (from "just meet the standard" to "get today's work out today and be flexible"). At the initiation of its efforts, DDCO had just experienced a 20 percent personnel loss with no decrease in workload (in figure above, costs are shown by line graph keyed to the ordinate on the right) and faced a variety of tasks, such as backlogs and facility and stock cleanup, that were an additional burden to reducing the depot's response time to its customers. DDCO has reduced the time to process routine orders by 70 percent, and costs have not risen.⁶² The depot was able to achieve these dramatic improvements in response time within only a few months. For its efforts, DDCO was designated as a Hero of Reinvention as part of Vice President Al Gore's National Performance Review.⁶³

⁶² Costs at DDCO consist of fixed and variable costs. *Variable costs* include overtime, packaging, and transportation and are a function of both volume and how DDCO operates. Some months did result in modest increases in packaging, transportation, and overtime costs, but, as shown in the figure above, these increases were not significant (Vick [1994]).

⁶³ Defense Performance Review (1994), p. 4.

Coronet Deuce Demonstrated How Reducing 'Moves' and 'Waits' Speeds Depot Repair



Improved performance resulting from another process-improvement effort by a DoD logistics provider is depicted in the above bar chart. In a recent exercise called Coronet Deuce, the Air Force dramatically reduced the repair cycle of 32 high- and very high-value components of the F-16 fighter. Under the original system, both kinds of parts took about 32 days to move from the aircraft, to depot-level repair, and back to stock. The Air Force made a series of process improvements designed to increase the velocity of materiel and information movement.

First, very high-value parts were given special visibility and treated differently within the depot-handling process to move them through very quickly.⁶⁴ Second, high-value items were added to the process-improvement effort. The on-base processes to move both the very high- and high-value items off the base to the depot were streamlined to improve responsiveness. Then the total repair-cycle time within the depot was also treated as a more comprehensive process. Third, the Air

⁶⁴ This practice is quite common among the best private-sector logistics providers. High-priority jobs and all jobs for items over a given dollar value are processed through a special channel. This practice is quite different from a one-size-fits-all approach to logistics. An excellent reference on this tailored approach is Fuller et al. (1993).

Force prepositioned serviceable Shop Replaceable Units (SRUs) at the depots so that the more valuable Line Replaceable Units (LRUs)⁶⁵ would not have to wait while faulty SRUs were identified and repaired. The reduction in cycle time was 81 percent for high-value and 75 percent for very high-value components.

A simulation of these improvements estimated that the Air Force could save over \$10 million/year in operating and support costs⁶⁶ and still sustain the same levels of weapon system availability achieved with the old system. Furthermore, the Air Force has continued to reduce repair-cycle times for these components.⁶⁷

These efforts are being extended to other weapon systems and shops. Currently, process-improvement efforts are under way for the C-5 and E-3, as well as for numerous individual shops (e.g., hydraulics, radar-navigation, and communications-electronics), at the Air Force's different Air Logistics Centers.

⁶⁵ SRUs are components (e.g., circuit cards) of the more expensive LRUs.

⁶⁶ The simulation was for 403 Block 40 F-16 aircraft. Estimated savings does not include future savings in inventory cost from any churn (the effects of reduced inventories as different types of items are removed and added to the inventory due to modifications or upgrades). It is not yet clear how this result will generalize for other components or aircraft.

⁶⁷ Abell and Shulman (1992).

DoD Logistics Providers Have Initiated Process Improvements

- **Army - Velocity Management**
- **Air Force - Lean Logistics**
- **Navy - Customer Wait Time**
- **Marines - Asset Tracking for Logistics and Supply System (ATLASS)**
- **USTRANSCOM - Defense Transportation System 2010**
- **Defense Logistics Agency - Buy Response Vice Inventory**

The experiences of the DLA with the Columbus Distribution Depot and the Air Force with Coronet Deuce are just two examples of process-improvement efforts under way by DoD logistics providers. Other efforts for different process segments and types of materiel are ongoing. Furthermore, each of the major DoD organizations providing logistics services has begun far-reaching programs to implement and propagate process improvements more widely. This chart lists elements of some of these programs. The intent is not to evaluate or to be exhaustive but to give a flavor of the kinds of initiatives under way.

VELOCITY MANAGEMENT

The Army has an initiative referred to as Velocity Management that is being implemented by a coalition of senior logisticians headed by the Deputy Chief of Staff for Logistics. The goal of the initiative is to move the Army logistics system to a new paradigm based on highly responsive and efficient logistics processes rather than on massive inventories of materiel. The initiative is focusing initially on reducing the order-and-ship time and the repair-cycle times associated with critical major weapon systems, including the Apache helicopter and the M1A1 battle tank. The improved cycle times will result in improved responsiveness to customers' needs, improved robustness in dealing with

demand uncertainties, and cost savings from reduced materiel, labor, management, and infrastructure costs.

LEAN LOGISTICS

The Air Force has embarked on a two-pronged effort to test and develop a lean logistics system. In one prong, it has established a Lean Logistics Steering Group representing all the commands. This group is developing and testing an implementation master plan and coordinating lean logistics activities with DLA and other DoD agencies. The Air Force has many ongoing weapon-system-specific lean logistics efforts. For example, for the C-5 cargo jet, the Air Force has revamped the handling of selected items in the field and has moved them more rapidly through the depot repair shops. During the B-1 Dakota Express test, some of the lean logistics principles were used (e.g., streamlined base and depot handling). In the second prong, the Air Force Materiel Command's five Logistics Centers have begun to develop and implement innovations to improve the flows through all the repair shops.

CUSTOMER WAIT TIME

The Navy has a new Customer Wait Time initiative to reduce the time it takes to fill a maintenance requisition. It has developed a plan of action and milestones for assigning responsibility, developing and monitoring measurement, improving data and measurement, maintaining corporate focus, and improving the processes to reduce each customer wait-time segment. A number of milestones have already been completed, including measurement of the submission, Inventory Control Point processing, stock-point processing, transportation hold, transportation shipment, and receipt take-up times for Navy requisitions. Efforts are ongoing to streamline the administration lead time for repair processes.

ATLASS

One of the Marines' initiatives to improve its logistics processes involves the deployment of a new retail (unit-level) logistics information system, Asset Tracking for Logistics and Supply System (ATLASS). Their retail process is improving as part of that deployment. The Marines also have several other smaller initiatives, including one that looks at substituting transportation (speed) for inventory.

DEFENSE TRANSPORTATION SYSTEM 2010

USTRANSCOM has recently published *Reengineering the Defense Transportation System--The "Ought to Be" Defense Transportation System for the Year 2010*, and an action plan, *Reengineering the Defense Transportation System--The DTS 2010 Action Plan*, to move from today's fragmented structure and processes to an integrated Defense Transportation System that is customer-focused, responsive, and efficient. The DTS is a Reinvention Laboratory within the Defense Performance Review (DoD's efforts in the National Performance Review).

BUY RESPONSE VICE INVENTORY

The Defense Logistics Agency has a number of initiatives to improve performance. Fourteen have been designated as reinvention laboratories⁶⁸ within the Defense Performance Review. Its Buy Response Vice Inventory initiative seeks to speed up DLA's internal processes, such as inventory management, supply, and distribution. DLA has recently created the Logistics Response Time Management File, a database it can use to measure and assess trends and to diagnose how to improve performance. It also has a new Premium Service program with Federal Express in Memphis, Tennessee, for express handling and delivery of expensive, scarce, or low-density items.

OTHER DOD IMPROVEMENTS

Besides improving logistics processes performed by DoD organizations, DoD, like industry, is contracting out some of its logistics services. For example, the Air Force had a \$120M/year Log Air system that used contract airplanes and in-house people to transport spare parts (piece parts to engines) between Air Logistics Centers and depots and tactical air bases. It contracted out this service to overnight carriers, increased overnight delivery from 92 to 98 percent, and reduced costs by about \$73M/year. DLA is contracting out supply and distribution via a Direct Vendor Delivery (DVD) program. Under DVD, requisitions are routed directly to the vendor, who then ships directly to the customer. DLA has a DVD goal of 50 percent of sales (less fuels) by FY 97. Initiatives are also under way to be a more demanding

⁶⁸ "Designation as a reinvention laboratory signals a large scale effort to apply all of the principles of the National Performance Review through the organization" (Defense Performance Review [1994], p. 4).

customer of current private-sector providers (e.g., many DoD organizations are establishing contracts with more-demanding delivery times for smaller and more-frequent deliveries of materiel).

The above initiatives⁶⁹ represent significant efforts to improve the performance of DoD's key logistics processes. The details of the designs and implementations vary by institution and by commodity (e.g., high-tech spares, munitions). They also differ in their reliance on information systems, premium transportation, and other enabling technologies. Nevertheless, all these efforts have a common thread: They emphasize leaner, more responsive logistics systems and move away from the paradigm of mass logistics.

⁶⁹ RAND is closely involved in both the Army's Velocity Management (see Dumond, Eden, and Folkeson, 1994b) and Air Force Lean Logistics (see Cohen, Pyles, and Eden, unpublished draft) efforts and is beginning work with DLA. These efforts involve communicating the need for change, establishing what needs to change (often by measuring performance and critically reviewing one's own processes), ensuring that incentives are consistent with the desired change, and addressing other critical implementation issues.

Some Recent Management Signals in the Right Direction

- **Government Performance and Results Act of 1993**
- **Sep 94: Defense Secretary Perry memo calling for 50 percent reduction in all DoD cycle times by the year 2000**
- **OSD 94 Logistics Strategic Action Plan calling for 72-hour CONUS order-to-receipt time by 1998**
- **Logistics Response Time Process Action Team**
 - **Working to establish measures of performance**
 - **Benchmarking process performance across DoD-owned providers**
 - **Identifying ways to increase responsiveness**

As well as DoD organizations that provide logistics services, discussed in the preceding chart, higher-level management has also rolled out initiatives intended to shift DoD logistics from a mass paradigm to a paradigm based on leaner and more-responsive processes. Such initiatives came as a result of the Government Performance and Results Act of 1993 (GPRA), in which Congress recognized the need to set and measure performance goals. GPRA requires federal agencies to

- develop strategic plans prior to FY 98
- prepare plans setting performance goals, beginning with FY 99
- report annually on actual performance compared with goals (first report is due in March 2000).

However, the extent to which the act will result in performance measures that map to cross-functional end-to-end process performance measures is not clear.

Recent policy statements from top-level logistics managers in OSD, including a memo from Defense Secretary William Perry and an OSD Logistics Strategy Action Plan, suggest that the need to move to more-responsive processes has been recognized. However, with the exception

of OSD's Logistics Response Time Process Action Team, these policy statements have not established a formal management process for ensuring that the goals are achieved, nor have they addressed the massive challenge of shifting the emphasis of DoD's logistics management processes and providing additional policies to encourage continuous improvement of all DoD's logistics providers.

How Much Can DoD Processes Be Expected to Improve?

- **Dramatic improvements in response time are possible**
- **Improved response times will have many benefits**
 - **Improved robustness**
 - **Improved quality through more timely feedback**
 - **Reduced costs through numerous avenues**
 - **Materiel savings through reduced pipelines, excesses, and churn**
 - **Simplified processes and management**
- **Cost savings are harder to estimate and will take more time to realize**

What kind of performance improvements can DoD reasonably expect if the initiatives in the previous charts and other process-improvement efforts are implemented?

For responsiveness, it is reasonable for DoD to expect order-of-magnitude improvements over today's typical performance and similar reductions in variability. Whereas order-and-ship times and repair-cycle times are currently reported in weeks and months, they should be reported in days. Reductions in procurement lead times can be just as dramatic by reducing internal processing (simplifying the process of moving from purchase request to purchase order) and production lead time (by moving to smaller, more-frequent deliveries). And whereas procurement times are currently reported in years or months, they should be reported in weeks or days, particularly for commercially available items.

As the analysis summarized in Section 2 suggests, changes required to reduce response times often result in or enable improvements in other dimensions of performance. For example, reductions in response time can contribute to the robustness of DoD logistics and result in a system better able to withstand the uncertainties associated with deployed operations. Reduced cycle times often result from simplified processes that have fewer handoffs and opportunities for the introduction of

errors and that enable more timely feedback for quality improvements.⁷⁰ Elimination of labor-consuming, non-value-adding activities will be necessary to reduce response times. Reduced materiel costs in the form of pipeline reductions will result directly from reduced response times. While at first blush inventory savings from pipeline reductions appear to be a one-time savings, the savings are in fact recurring because items enter and leave the inventory on a recurring basis (e.g., some items are discontinued, resulting in excesses, while other items are added, requiring inventory for pipelines to be purchased). However, benefits along the other dimensions are much more difficult to estimate. For example, current logistics costs for DoD organizations are difficult to establish, to say nothing of predicting reductions from process improvements.⁷¹

There are also reasons to believe that benefits along some of the dimensions other than responsiveness may be more difficult to achieve. Whereas shifting from mass logistics will require eliminating non-value-adding activities and reducing management hierarchies, labor reductions are also required by the overall drawdown of DoD and the combat forces, which are the primary customers of DoD's logistics processes. Because DoD logistics is a shrinking business, it is not possible for DoD organizations and some of DoD's private-sector providers to "grow" the business; hence, efficiency gains will necessarily be more painful and difficult to achieve than for a firm that can expand its customer base. Also, cost reductions may take more time to realize than response-time reductions, considering that many efforts at reengineering processes have required up-front cost increases.⁷²

The size and complexity of DoD logistics mean this change process cannot happen overnight. Improving processes throughout the DoD logistics system, both public and private, is the equivalent of having an entire industry make a transition through multiple tiers of suppliers and interrelated processes to a different paradigm (i.e., mass to lean production). The interrelationships mean that synergy will be necessary and that each individual improvement effort can be complicated by

⁷⁰ Examples of how lean production has led to more timely feedback and has resulted in improved quality can be found in Womack et al. (1990).

⁷¹ Very rough estimates based on DBOF expense data for DoD logistics enterprises that are subject to private-sector-like reductions suggest potential annual savings could be measured in billions of dollars (Hanks, unpublished RAND briefing).

⁷² Hammer and Champy (1993).

laggards. For example, because of parts-availability problems, it will be difficult to improve the repair process if the distribution process is not more responsive and reliable (much as a lean-production assembly plant requires responsive and reliable suppliers and a developed distribution infrastructure).

Although DoD logistics providers as a whole have lagged the private sector in implementing process improvement, some have already demonstrated the capability to achieve dramatic performance gains through process improvement. In other areas, DoD has shown dramatic improvements in performance by outsourcing or shifting work to higher-performing providers. That dramatic improvements in the performance of logistics processes are possible is heartening; moreover, these examples have shown that there is some "low-hanging fruit" that can be picked easily for quick local improvements. However, while much can be accomplished by changing local standard operating procedures (SOPs) and by measuring performance, benchmarking, and other efforts, process improvement (whether done internally or by contracting out services) is generally a very difficult enterprise in DoD's current environment.

Policy changes or up-front investments may be needed to allow DoD logistics managers to better manage their processes or providers for high performance. Comprehensive and enduring reform of all DoD logistics processes (i.e., shifting from the mass-logistics paradigm), along the lines of the initiatives described earlier in this section, could take years to implement. External pressures on and a close working relationship with logistics providers will no doubt be critical to achieve the long-term success of these initiatives and to establish a basis for implementing continuous improvement in DoD's logistics processes. Feedback on process performance will be needed to differentiate high-performing providers.

Achieving all the benefits of high logistics performance is going to require a significant, sustained, and highly focused effort by all of DoD's logistics managers. We turn to the central role of management in the next section.

Outline

- DoD logistics processes must improve along multiple dimensions of performance
- Implementation of process improvement has led to high performance in the private sector
- Process-improvement efforts are ongoing in DoD logistics
- *Strategies for improving DoD logistics must be developed and implemented*

The research summarized in the previous sections delivers three messages:

- Most of DoD's logistics processes perform poorly relative to both comparable processes in the private sector and DoD's own performance standards.
- Many private-sector corporations have attained improvements in response times and costs, as well as in flexibility and quality, by focusing on process⁷³ improvement or outsourcing to high-performing providers.
- There is considerable potential to improve DoD logistics processes, and numerous initiatives are under way.

The first message often leads to different interpretations. To some, the empirical data documenting the poor performance of DoD's current logistics processes lead to an emphasis on improving logistics

⁷³ We emphasize again that the focus should be on *processes* (e.g., distribution), rather than on *functions* (e.g., supply management and warehousing). Because many processes cut across functions, particularly as functions are commonly defined within the DoD, concentrating on processes shifts the focus to the component elements of how outputs are produced for customers.

performance as a source of significant savings. To others, this same poor performance, coupled with the research on uncertain demands, implies that the focus should be on improving logistics support to the customer, particularly warfighters in deployed operations. Because resources are always constrained, effectiveness and efficiency are necessarily related. However, the second message implies that there is not necessarily a trade-off between the two. The experience of the private sector, documented many times in diverse contexts, is that when an enterprise is not performing to acceptable standards, achieving *both* improved effectiveness and significant cost savings is feasible.

In this section, we further investigate the third message and discuss the success factors and impediments associated with initiatives to improve DoD logistics. We outline a framework for identifying and managing initiatives to improve DoD logistics performance. Finally, we raise issues associated with implementing the framework.

DYNAMIC, PERFORMANCE-BASED MANAGEMENT

The most effective means of improving performance will likely vary across the wide variety of processes, organizations, and types of materiel in DoD logistics. Successful approaches to improve performance in one area may be less successful when applied to other areas. Also, while numerous initiatives to improve DoD logistics are under way, to what extent those initiatives will be successfully implemented and what performance gains will result are not clear. DoD's logistics management needs to be able to actively guide initiative selection and to enable existing performance-improvement initiatives while learning which approaches provide the most promise. One method for achieving both objectives is dynamic, performance-based management. *Dynamic, performance-based management* is a three-step framework that (1) establishes clear goals, (2) collects decisionmaking information, and (3) guides selection of initiatives to improve performance and enables their implementation.

1. Establish Clear Goals

The first step in the framework is to establish and periodically revise a vision of high performance and to quantify the vision by defining metrics and associated performance standards. Metrics (e.g., responsiveness, cost, quality, and flexibility) should be defined for the logistics processes and the outputs of the processes (e.g., weapon

system availability). Standards should be based on customer requirements and the best performance in the public or the private sector; they should be defined in a way that provides feedback to those carrying out the process.⁷⁴ Finally, top managers must be committed to these goals and emphasize their importance.

The current vision of DoD logistics is still largely driven by the mass-logistics paradigm developed during World War II.⁷⁵ The sheer size of DoD logistics, frequent turnover in leadership (e.g., political appointees, senior executive service [SES], and general officers), and fragmented responsibilities (i.e., by function rather than by process) are three reasons why current efforts to shift the DoD's logistics vision will take time to penetrate the institutional fabric of DoD logistics. The size and complexity of the logistics system will continue to be a challenge, but coalitions of DoD logisticians can work together to implement improvements, despite the fragmentation⁷⁶ of processes across organizational boundaries (and without having to wait for vast reorganizations). Also, because SES and general officers often rotate through related jobs, coalitions can provide some measure of continuity.

2. Collect Decisionmaking Information

Collecting decisionmaking information is an ongoing process. The primary purpose of the collecting is to continuously measure the performance of logistics processes and to compare that performance with standards and performance leaders outside DoD. A second purpose is to identify, diagnose, and fix failures so that they do not recur; a third is to determine when to periodically revise standards upwards.

Within DoD logistics, performance measurements are often incomplete or are supported by poor data quality.⁷⁷ The sparseness or suspect

⁷⁴ For example, standards for response times are best expressed as maximums or absolutes so that each failure (output of the process exceeding the standard) is readily apparent and can be diagnosed.

⁷⁵ Setear et al. (1990).

⁷⁶ Many existing performance standards measure only local segments of larger processes in terms of fill rate or full truckload. Consequently, the performance of the overall system is suboptimized. A good example showing the multiple measures of performance used in the distribution process is found in Moore et al. (unpublished draft).

⁷⁷ Many data systems in DoD logistics are still limited to the data that fit on an 80-column computer punch format, and source-data capture (e.g., bar codes and laser cards) has not been universally embedded into business processes. The result is often inaccurate or missing data.

quality of measurements complicates the diagnosis of the underlying causes of poor performance. However, DoD can initially focus on simpler measures, such as response time (confident that improvements in response time will likely result in improvements along other dimensions of performance) and add increasingly sophisticated measures as processes and supporting data systems are improved.

As noted earlier, current UMIMPS standards for the wholesale order-and-ship process are not being achieved. This failure suggests that measuring performance and diagnosing failures will require a strong commitment from top logistics managers to insist on getting feedback on process performance and to act on that feedback.

3. Guide Selection and Enable Implementation of Initiatives

As was the case in the private sector, DoD logistics managers can choose initiatives from two broad categories: process improvement with existing providers and outsource to high-performing providers.⁷⁸ Numerous criteria can be used to guide this decision, including feasibility and likelihood of success, timing and magnitude of expected performance gains, and short- and long-term risk.

For example, a candidate for outsourcing would be CONUS-based wholesale services provided by a low-performing DoD logistics provider for which a productive and competitive market exists and DoD represents a small portion of the overall market.⁷⁹ On the other hand, logistics services in markets with high entry costs and no clear high-performing alternatives to current DoD providers are candidates for process improvement.⁸⁰ In many cases, the appropriate choice of performance-improvement initiatives will not be clear cut. In all cases, when current providers are performing poorly, both process improvement and outsourcing will likely have substantial potential for improving performance.

⁷⁸ To avoid confusion, the discussion in this section is posed as though the existing provider is a DoD organization. If the existing provider were a private-sector organization, the options would be more appropriately called (1) work with provider to implement process improvement and (2) shift to a high-performing provider.

⁷⁹ Possible examples include the overhaul of commercially comparable DoD equipment (e.g., diesel engines) and the operation of warehouses.

⁸⁰ Possible examples include theater distribution and repairs that are military-unique (e.g., fire control for combat aircraft) and require significant capital investment (e.g., unique test equipment).

The intent of the framework is to provide a methodology whereby DoD logistics managers can obtain the best available information to assess the selection criteria, using analysis instead of anecdotes to choose the appropriate initiatives. Thus, to assess whether process improvement or outsourcing is appropriate would require an analysis combining standards (including benchmarks used to establish the standards), performance measurements, and diagnosis with estimates of the magnitude and timing of expected benefits and costs, associated risks, and likelihood of successful implementation.

A complicating factor is that DoD managers can influence the potential of both process improvement and outsourcing. This potential influence increases as one moves up the management hierarchy, because the breadth and depth⁸¹ of logistics management opportunities and options increase with "height." Changes in policies, laws, regulations, ownership, lines of authority, and organizational structures (which we refer to collectively as *changes in governance arrangements*) can affect how an initiative will be assessed with respect to the selection criteria.

We now briefly discuss how governance changes can enable both process improvement and outsourcing initiatives.

Enabling Process-Improvement Initiatives. DDCO and Coronet Deuce are just two examples of the potential in DoD logistics for process-improvement initiatives. And most of the ongoing initiatives by DoD providers described earlier also fall into the category of process improvement (although DLA's DVD initiatives result in the de facto contracting out of segments of the distribution process). Successful implementation and proliferation of existing successes require that logistics managers recognize and reinforce critical success factors and

⁸¹ Both breadth and depth are critical factors in success. *Breadth* is the reach of improvements: The more activities that are included in the process-redesign effort, the more likely it is that improvements will extend throughout the entire organization. When interrelated activities are included, steps can be combined, and delays, errors in handoffs, and the source of problems can be removed. *Depth* increases the likelihood of success and involves the complete restructuring of the key drivers of behavior (roles and responsibilities, measurements and incentives, organizational structure, information technology, shared values, and skills) from the operational process upward through management layers (Hall et al. [1993]).

remove impediments⁸² by working with the champions of these process-improvement initiatives.

Reorganizations are an example of a governance change that can be used to enable process improvement, because they can increase scale (either to achieve economies⁸³ or to establish sufficient breadth of resources to achieve flexibility). For example, consolidating maintenance activities may provide sufficient scale to respond to uncertain demands by surging repair of some items. Reorganizations that promote an overall process focus can also help improve performance. For example, eliminating echelons of supply or repair and consolidating end-to-end authority. However, these benefits must be weighed against up-front costs. And, reorganizations can create turbulence that saps management energy and shifts the organizational focus away from process improvement.

While changes in governance can be used with process improvement, one advantage of process improvement is that it can be done within the existing governance framework (in fact, process-improvement efforts often suggest governance changes, so feedback on process-improvement initiatives is key). Because changes in governance can take time and DoD needs improved performance now, process-improvement initiatives are particularly appropriate for the shorter term. In fact, all of DoD's current logistics providers can apply process improvement (although there will likely be varying degrees of success).

Enabling Outsourcing Initiatives. DoD's need for higher logistics performance, the ongoing revolution in commercial logistics practices and performance, and the close parallels between many of DoD's wholesale logistics processes with commercial logistics suggest that outsourcing be given very careful consideration. For some wholesale logistics activities, outsourcing appears to have very little risk (in both short and long terms) and high potential for substantial performance gain

⁸² Impediments to process improvement include institutional resistance to change, lack of appropriate incentive structure (often driven by local financial considerations), personnel policies, government regulations, need for up-front investments, and organizational boundaries.

⁸³ The need for process improvement in DoD logistics is a related but different issue from the need to downsize DoD logistics (e.g., to reduce the costs associated with redundant activities) or to reduce excess capacities, which has driven some recent reorganizations (consolidations).

(e.g., wholesale distribution and some wholesale repair activities). Also, outsourcing appears preferable to DoD making large investments in capital and other resources with no guarantee of even reaching *current* commercial performance (which may well be a moving target) in a timely fashion.

However, there are reasons to exercise caution. DoD's current measurement systems and management processes do not provide all the information needed to make informed choices. As well as these uncertainties, DoD will be faced with numerous constraints in implementing outsourcing initiatives. These constraints include mixed incentives for DoD logistics managers, regulations constraining the selection of high-performing providers, high transaction costs, limited ability to enter into long-term partnerships, limitations of existing contracting vehicles, and limited ability to reduce the number of suppliers.⁸⁴ To increase the expected gains, reduce the risks, and increase the probability of success of outsourcing initiatives, some of these issues will have to be addressed. The services and DoD line agencies (e.g., DLA) should establish perceived constraints on outsourcing, and these constraints should be discussed and addressed (ultimately OSD may have to raise some issues with Congress).

Unlike process improvement, outsourcing cannot begin immediately in all logistics providers. Besides the current constraints, it would take years for industry to absorb,⁸⁵ and for DoD to write, all the complex contracts necessary to outsource most of the logistics services currently provided by DoD organizations. For example, problems negotiating the return or eventual distribution of large DoD inventories may be an obstacle to the complex contracts required to establish a DVD program. Hence, DoD may want to be more selective in establishing outsourcing initiatives (i.e., versus process-improvement initiatives, which should begin immediately in all areas).

⁸⁴ Camm (unpublished manuscript) discusses shortcomings in DoD's ability to select and contract with private-sector providers and suggests a two-step approach to privatization: First, raise and address the many objections and barriers to privatization; second, develop a framework for pursuing privatization.

⁸⁵ Cass Logistics, Inc., estimates 1994 revenues in contract logistics at \$16B and projects revenues of \$25B in 1996 (Delaney [1994]). Contracting out all of DoD's \$11B in wholesale logistics operations provided by DoD organizations would be difficult. The highest performers in this rapidly growing industry may choose not to accept the high transaction costs of doing business with the DoD when they are already straining to meet their commercial customers' growth demands.

One of the key questions addressed in outsourcing logistics in the private sector is whether logistics is a core⁸⁶ process. Many corporations have outsourced logistics processes to focus resources on their core business processes. However, a gap in performance has also played a major role in many of these decisions. Many corporations have found themselves with a logistics process based on the mass-logistics paradigm while facing competitors with logistics processes that are more efficient and an order of magnitude more responsive. Unwilling to invest the capital and management resources required to improve performance to a competitive level but eager to improve the delivery of services and products to their customers, many companies have decided to outsource logistics processes. On the other hand, other corporations have used their expertise in logistics as a source of competitive advantage and have even begun to contract out their services as a new line of revenue.⁸⁷ Hence, in the private sector, deciding which processes to retain and develop is a function of both mission and where a firm sees a source of current or future competitive advantage.

Although DoD's mission is critical, DoD also needs high logistics performance today and in the future. Thus, the DoD must move away from its current static and risk-averse definitions of *core*⁸⁸ and move toward a definition more in line with that used in the private sector, emphasizing *both* mission and current or future competencies.⁸⁹

Given the above cautions, outsourcing holds considerable promise. Indeed, the spectacular rise in the number and size of firms that provide logistics services to others (third-party or contract logistics) has resulted in there being few logistics services that cannot be contracted out. Thus, while outsourcing has much to offer DoD, implementing it will be difficult without substantial changes in how DoD gains access to private providers. Also, if the shift to increase

⁸⁶ In the private sector, a *core business* is one that the company's management and board have decided is the business they know, are good at, and plan to focus on.

⁸⁷ For example, although Caterpillar primarily designs and manufactures heavy equipment, it is also recognized as an industry leader in logistics and has formed Caterpillar Logistics Services to provide logistics services to other companies.

⁸⁸ In DoD, *core* usually means a service critical to warfighting, a narrower definition than industry's. The DoD's use of the term misses the crucial aspect of self-examination to decide whether DoD is any good at the function or business.

⁸⁹ See Prahalad and Hamel (1990) and Quinn and Hilmer (1994).

outsourcing is rushed and done improperly, a backlash against future outsourcing could result.⁹⁰

STRUCTURAL CHANGES TO FACILITATE DYNAMIC MANAGEMENT

While DoD has begun to take steps in the right direction, there is little to suggest that the current management processes can quickly or easily adopt the dynamic management framework described above. Rather, the current management processes and structures have failed to date to provide the vision, measurements, and analysis necessary to foster logistics excellence. As with a corporation that has dramatically underperformed in an industry, DoD's own management processes may need to undergo major changes.

Independent Defense Logistics Board

The question then becomes how to implement the framework in a manner that will shift the focus of DoD's management processes. Again looking to the private sector, we see that the boards of major corporations have initiated recent changes in high-level management (e.g., General Motors⁹¹ and Kodak), suggesting there may be something for DoD to learn from such changes in corporate governance. DoD may want to investigate the option of adapting corporate practices and establishing an independent, outside board for assessing the overall performance of DoD's logistics processes and high-level DoD management. The board would be responsive to the Secretary of Defense, who has the ultimate responsibility for DoD management.

Here, *independent* implies that the board should include directors from outside the DoD who are familiar with the dynamic environment of commercial logistics (e.g., industry and academics) and can help identify major trends in technology and business practice and bring them to the attention of senior DoD managers.⁹² The board should also

⁹⁰ For example, see "Hiring Outside Firms to Run Computers Isn't Always a Bargain," *The Wall Street Journal*, May 18, 1995.

⁹¹ See Ingrassia and White (1994) for a description of how boards have been involved in changes to top-level management in the automotive industry.

⁹² Congress has regulatory and budget authority but has proven itself to be anything but independent, nor are its members generally knowledgeable about cutting-edge logistics. As discussed, many of the constraints placed on DoD management have been imposed by Congress. While DoD has other boards in the logistics area (e.g., the Defense Business Operations Fund has a corporate board), it is not clear that those boards regularly include members from outside DoD. The Defense

include retired military and congressional leaders who are familiar with the incentives and needs of stakeholders in DoD logistics and the history of how and why current policies have evolved. While it is possible to form an independent advisory board, problems may arise in empowering the board to follow the governance practices that boards have set up in the private sector. Rather, an advisory board (e.g., Defense Logistics Board) may be appropriate.

Reorganization

Reorganization of management structures may also contribute to implementing the framework and establishing a more dynamic, performance-based management process. Because management processes have a longer-term focus and are further removed from day-to-day operations, they are more amenable to reorganization and involve less immediate risk to operational performance and customer satisfaction.

Two factors make management reorganization particularly desirable. First, reorganization can help improve management's focus on end-to-end logistics process performance by aligning high-level management along the key logistics processes (e.g., repair, distribution, and procurement). Second, reorganization can be used to dramatically flatten management hierarchies, as has been done in the private sector.

Neither process improvement nor outsourcing can, by itself, deliver all the needed benefits. Each type of initiative has strengths and weaknesses, particularly when viewed in light of the vast variety of materiel and services encompassed by DoD logistics. Building adaptability and innovation into DoD logistics management processes is arguably the most critical factor in improving the performance of DoD's logistics processes. Hence, it is not the *specifics* of the framework presented above that are most important but the *shift in emphasis* that it implies for DoD logistics management. This framework, or one like it, should be as pervasive at all levels of DoD logistics management as is the PPBS process.

THE OPPORTUNITY FOR PERFORMANCE IMPROVEMENT

The DoD urgently needs both logistics cost savings and improvements in multiple dimensions of effectiveness. Fortunately, the current downsizing environment provides DoD with an important opportunity to

Science Board regularly impanels "Boards" of outside experts as Task Forces, but they are, by definition, temporary.

promote process improvement, much as global competition has driven the private sector to process improvement. However, the same environment is forcing decisions almost daily. For example, many DoD logistics providers, both public and private, are being eliminated through the Base Realignment and Closure process. Some of these decisions may be the same as those that would be made under a dynamic, performance-based management process. But others (e.g., retaining low-performing providers), well-motivated as they appear today, may be regretted over the long run. And with the loss of each provider, options for future decisions may be constrained. DoD needs to accelerate and manage the process of change to ensure that the best-performing logistics providers--and those with the most potential--are the ones that survive, and that poorer performing providers are the ones that disappear.

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This report explores issues in forecasting and modeling the demand for aircraft recoverable spare parts to improve the Air Force's estimation of spares and repair requirements over quarterly, annual, and longer planning horizons. Specifically, it demonstrates the utility of approaches that account explicitly for nonstationarity and their superiority over current methods used by the Air Force Materiel Command for these purposes. The authors recommend using a weighted regression, a special case of the Kalman filter, for forecasting demand for high-demand items. This approach is a logical extension of Bayesian statistics, which explicitly accounts for nonstationarity in stochastic processes, assigning greater weight to more-recent than to less-recent demands. Coupled with an improved approach to variance estimation that assigns greater uncertainty to longer planning horizons than to shorter ones, it holds the promise of reducing the cost of spares investments while achieving adequate levels of system performance.

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Brady, Steve, John Dumond, Rick Eden, and John Folkeson, "A New Approach to Supporting Depot-Level Maintenance Policymaking," RAND, Santa Monica, CA, unpublished draft.

DoD and Army leaders have recognized the need to downsize logistics capabilities appropriately as part of the ongoing drawdown of U.S. military forces. However, recent efforts by the Army to consolidate some repair depots and close others have met with resistance. Additional efforts to improve the efficiency of the industrial support operations by encouraging competition for some of the industrial-based workload among public and private organizations have met with only limited success. In order to pursue needed reforms aggressively, Army leaders need an improved capability to develop policies with strong analytic underpinnings. In addition to being effective, such policies can be readily explained and defended. This draft describes the preliminary results of efforts to develop a decision aid to provide such a capability. The decision aid is based on a mathematical programming model for determining required levels and optimal allocations of manpower and facilities for maintaining various weapon systems under a variety of economic, political, and operational constraints.

Brown, B. B., *Characteristics of Demand for Aircraft Spare Parts*, RAND, Santa Monica, CA, R-292, 1956.

The results of various RAND studies on the demand for aircraft spare parts. Ways are devised by which the demand pattern can be estimated for the insurance-type items, and certain stockage and procurement procedures are suggested in the case of unpredictable demands. This report may aid in specifying the overall design of the logistics system and the policies for distribution and requirements that the system should follow. Presents the results of various RAND studies on the demand for aircraft spare parts. To reduce the occurrence of parts shortages to a reasonably low level, it is necessary to predict the probability that various demands will occur. However, demands cannot be predicted with confidence, so it is necessary to consider improvements in logistics operations to make it easier to live with demand uncertainty. Suggested improvements are

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Cohen, Irv, Jack Abell, and Tom Lippiatt, *Coupling Logistics to Operations to Meet Uncertainty and the Threat (CLOUT): An Overview*, RAND, Santa Monica, CA, R-3979-AF, 1991.

Uncertainty is of essentially two kinds: statistical uncertainty (variability observed in repeatable phenomena), and state-of-the-world uncertainty (uncertainty about phenomena that are not repeatable, not observed or observable, or both). State-of-the-world uncertainty dominates the wartime scenario and affects peacetime planning as well. This report describes a set of initiatives called CLOUT (coupling logistics to operations to meet uncertainty and the threat) designed to cope with resource shortages caused by poor predictions of demand. The theater-level CLOUT initiatives include (1) lateral repair by bases that have repair capability to support bases that do not; (2) forward stockage for quick response to unsatisfied demands at bases; (3) responsive theater transportation to support lateral resupply, forward stockage, lateral and theater repair, retrograde, and distribution of assets coming into the theater; and (4) improved operating policies and decision rules in prioritizing repair assets and allocating them to bases. The "wholesale" or depot-level CLOUT initiatives include the following:

(1) responsive, assured intertheater transportation; (2) enhanced flexibility, responsiveness, and relevance of the depot's repair process; and (3) distribution of serviceable assets that explicitly accounts for mission urgency and the current asset position worldwide. (See also R-3318, R-3612, R-3637, R-3888, R-3942, R-4158.) 55 pp. Bibliog.

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Correll, John T., and Colleen A. Nash, "The Industrial Base at War," *Air Force Magazine*, December 1991, pp. 52-56.

Crawford, Gordon B., *Variability in the Demands for Aircraft Spare Parts: Its Magnitude and Implications*, RAND, Santa Monica, CA, R-3318-AF, 1988.

Mathematical models of the logistics system are used to determine spares requirements, and they play an important role in evaluating logistics policies. The kernel of many, if not most, of these models is the modeling of the failure process and the resulting series of random demands on supply and maintenance. This report describes the assumptions of these models and quantifies ways in which the behavior of the data differs from the assumptions of the models. The differences are pervasive and important. In addition, an examination of the number of parts in the repair pipeline over time reveals even more variability than does the number of demands over time. These observations have two important consequences: (1) excessive demand variability substantially reduces the confidence we can put in our requirements and capability assessment models, and (2) highly variable repair pipelines with means larger than assumed by requirements models have a damaging effect on aircraft availability and wartime readiness. Depot policies, decisions, and goals should be aimed at reducing the number of parts in these pipelines and at increasing aircraft availability and wartime readiness. 88 pp. Ref.

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This briefing presents an executive-level overview of velocity management, a concept for dramatically improving the responsiveness and efficiency of the Army logistics system. Velocity management aims to substitute velocity and accuracy for mass in the logistics system. Reducing the cycle time of logistics processes promises the possibility of greater system responsiveness to the user's needs while permitting reductions in the size of safety stocks or days-of-supply that currently choke the system without adding much to achieved sustainment. Commercial firms that have adopted this general approach have achieved substantial, sometimes order-of-magnitude, improvements both in cost and, more importantly, in effectiveness in meeting their customers' demands. The approach requires the analysis and reengineering of processes--e.g., supply, repair, and transportation process--to eliminate non-value-adding activities and to continuously improve the productivity of value-adding activities. The briefing proposes how the Army, working with RAND, might proceed

in moving the velocity management concept from the development phase to a pilot implementation. It proposes formation of a senior coalition to provide the leadership and vision for change, to set broad goals and guidelines, to help waive Army regulations and other official policies, and to interface and coordinate with other DoD players, such as USTRANSCOM and DLA, as well as with contractors.

Dumond, John, Rick Eden, and John Folkeson, "Draft Velocity Management Pilot Implementation Plan," RAND, Santa Monica, CA, unpublished draft.

Velocity Management is an approach for improving the responsiveness and efficiency of the Army logistics system. The approach seeks to improve dramatically the speed and accuracy of logistics processes, thus reducing the need for massive logistics resources. This briefing focuses on the application of Velocity Management to the Army's order-and-ship processes. An O&S Process Improvement Team was established that included representation from pertinent organizations across the Army. The PIT demonstrated the use of a methodology for systematically reengineering logistics processes for dramatic improvement. The PIT analyzed data that corroborated the widespread perception that order-and-ship processes of the Army currently perform slowly and unreliably and fail to meet UMIMPS standards. The PIT established challenging new goals that exceeded UMIMPS standards. It developed a reengineered processes designed to achieve the new goals and specified needed policy and software changes to be implemented. Implementation of the reengineered O&S processes will yield immediate benefits in both effectiveness and efficiency. The PIT recommended an aggressive rolling implementation of the reengineered processes at four sites, beginning in the summer of 1995.

Dumond, John, Rick Eden, Doug McIver, and Hy Shulman, *Maturing Weapon Systems for Improved Availability at Lower Costs*, RAND, Santa Monica, CA, MR-338-A, 1994a.

This report advocates an approach to reducing the reliability and maintainability (R&M) burden associated with advanced weapon systems such as the Apache helicopter and the M1A1 tank. Maturation development seeks improvements in detecting, reporting, isolating,

and removing component faults; it also identifies and implements changes to component design that improve R&M. *Maturation development* is a dedicated period of intense operation, data collection, and analysis immediately upon fielding a weapon system. Its purpose is to detect and isolate design deficiencies by intensively operating the components in a fixed configuration within the normal operating environment. Another key element is a well-developed management information system linked to an integrated R&M database to facilitate efficient and effective resolution of the R&M problems associated with high-tech components. Maturation development can be applied both to new systems and to major modifications of fielded systems. The potential benefits of maturation development are the achievement of fully designed system performance and a reduction in life-cycle support costs.

Dumond, John, Rick Eden, and John Folkeson, *Weapon System Sustainment Management: A Concept for Revolutionizing the Army Logistics System*, RAND, Santa Monica, CA, DB-104-A, 1994b.

This documented briefing advocates a comprehensive concept for managing the Army and DoD logistics systems--Weapon System Sustainment Management (WSSM)--and illustrates the concept by drawing on several RAND logistics studies. To meet future threats, the logistics system must become much leaner, more flexible, and more responsive. The most successful commercial firms have developed these same characteristics by adapting a new management paradigm. WSSM applies similar management concepts to improve the Army logistics system. WSSM identifies three strategies that can help the logistics system achieve improved performance at lower cost. The first strategy is to focus the entire system on meeting the needs of the "customer" (i.e., the operational commander). The second strategy is to design and redesign weapon systems to be more supportable. The third strategy calls for changes in the structure of the logistics system so that it depends less on mass and more on the speed and accuracy of its processes (repair, distribution, etc.). WSSM integrates much RAND logistics research conducted over the past several decades and is influencing Army and DoD policymakers through projects for several sponsors.

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MR-479/1-OSTP. At the beginning of the 1980s, the United States was the world's largest producer of machine tools and had developed a new technology--computer numerical control--that would soon revolutionize the industry. By the end of the decade, U.S. production amounted to less than half that of Japanese and German firms, and the federal government felt compelled to protect the domestic market. Despite a recent resurgence, the industry is far from recapturing lost market share. Concerned by this decline, Congress asked RAND's Critical Technologies Institute to conduct a comprehensive study of the machine-tool industry in the United States, Japan, Germany, and Italy. The study analyzes the causes of the U.S. decline and offers policy options for aiding its recovery.

MR-479/2-OSTP. This volume consists of the appendices to the machine-tool study main report, RAND/MR-479/1. Among the appendices are detailed studies of the Japanese, German, and Italian machine-tool industries; an assessment of the key current and future technologies for the machine-tool industry; and separate case studies of two key technology areas: computer numerical control and transfer lines. The volume also includes the results of focus groups with industry experts and data problems associated with industry studies.

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This report presents a new approach for evaluating weapon system reliability and maintainability (R&M). The approach is based on the frequency with which faults in equipment degrade its ability to dependably deliver the full measure of its designed capabilities, and on the efficiency with which maintenance technicians remove faults, thereby restoring those capabilities. The authors identify promising opportunities for strengthening policies and procedures that could address these weaknesses and improve the overall management of R&M. They make the following recommendations for strengthening the support process: (1) debrief pilots for all indications of faults, (2) track performance of avionics by equipment serial number, (3) share information about fault symptoms across maintenance levels (flight line to shop to depot), and (4) establish a special program to repair problem units or components. In addition to changes in the support process, the authors suggest some adjustments to the product-improvement process and the acquisition process. (See also R-2908/1, N-2479, N-2499, N-2549.) 85 pp. Bibliog.

Girardini, Kenneth, William Lewis, and Earl Gardner, "Measuring Order and Ship Time for Requisitions Filled by Wholesale Supply," RAND, Santa Monica, CA, unpublished draft.

Girardini, Kenneth, David Oaks, and Rick Eden, *Army Munitions
Distribution: Shifting to Meet the Demands of Force Projection*,
RAND, Santa Monica, CA, DB-127-A, forthcoming.

To better meet the challenges of force projection across a broad spectrum of contingencies and missions, the Army requires improvements in major processes of munitions distribution: unit deployment with ammunition basic load (ABL), sustainment by sealift and airlift, and information transfers and decisionmaking. Recognizing that the Army has undertaken positive changes to adapt to

force projection across contingencies and missions, the authors have identified four high-level opportunities for further improvements in the munitions-distribution process: (1) providing the capability to tailor ABL across missions; (2) using smaller, more frequent sealift deliveries; (3) simplifying the airlift process for faster response; and (4) improving information transfers and decisionmaking. To focus improvement efforts and to dramatically improve the performance of its munitions distribution system beyond the opportunities the authors have identified, the Army needs to establish challenging but realistic process goals in each of the three major processes (ABL, sustainment, and information). It should then create cross-functional process-action teams to identify additional process-improvement opportunities and to implement process change.

Grier, Peter, "The Other Industrial Base," *Air Force Magazine*, July 1992, pp. 50-52.

Hall, Gene, Jim Rosenthal, and Judy Wade, "How to Make Reengineering Really Work," *Harvard Business Review*, November-December 1993.

Hammer, Michael, and James Champy, *Reengineering the Corporation: A Manifesto for Business Revolution*, New York: Harpers, 1993.

Hanks, Christopher, "How Business Process Reform Could Affect DOD: Lessons from the Private Sector," unpublished RAND briefing.

Hodges, James, and Ray Pyles, *Onward Through the Fog: Uncertainty and Management Adaptation in Systems Analysis and Design*, RAND, Santa Monica, CA, R-3760-AF/A/OSD, 1990.

Policy analysis has always involved great uncertainty. Tools have been available for handling some of that uncertainty, but policy analysis work in many fields has fallen into stereotyped problem formulations and analytical approaches. In particular, treatments of uncertainty are typically incomplete and often conceptually wrong. This report argues that these shortcomings produce pervasive systematic biases in analyses. It describes and discusses the common mode of policy analysis and identifies its two main shortcomings--omission of crucial sources of uncertainty and neglect of systems'

ability to respond to the unexpected. It categorizes some varieties of uncertainty relevant to policy analysis and presents examples of ways they are commonly represented. Finally, it discusses designing and evaluating systems and presents a collection of generic strategies for uncertain situations. 32 pp. Ref.

Ingrassia, Paul, and Joseph B. White, *Comeback: The Fall and Rise of the American Automobile Industry*, New York: Simon & Schuster, 1994.

Isaacson, Karen, Patricia Boren, C. L. Tsai, and Ray Pyles, *Dyna-METRIC Version 4: Modeling Worldwide Logistics Support of Aircraft Components*, RAND, Santa Monica, CA, R-3389-AF, 1988.

This report describes Dyna-METRIC Version 4, a computer model that relates logistics resources and policies to wartime readiness. Developed for the use of logisticians to improve wartime logistics support, Dyna-METRIC assesses the effects of wartime dynamics and repair constraints and provides operational performance measures, problem detection, and spares requirements. Version 4 consists of five programs that provide for three echelons of interaction (including the depot-to-theater link) and three levels of components (for which demand processes, repair processes, and spares levels may vary). Dyna-METRIC portrays component support processes as a network of pipelines through which aircraft components flow as they are repaired or replaced within a single theater. Using the sum of all the pipeline segments, Dyna-METRIC determines the complete probability distribution for the number of parts in repair and on order. Combining the distributions for all components provides the estimate of aircraft availability and sorties. 212 pp. Ref.

Kassing, David, Kenneth Girardini, Brian Leverich, Richard Stanton, and Rick Eden, *New Tools for Balancing Theater Combat and Support*, RAND, Santa Monica, CA, DB-150-A, forthcoming.

This draft presents an overview of tools being developed to assist the Army in analyzing the effects of limitations on the size and speed of its deployments. The ROSE (RAND Operational Support Evaluator) model, a key product of this study, allows simultaneous input of combat and support plans; assesses the feasibility of combat and support plans; and is potentially useful with Army combat models

at several Army commands. The authors have identified three general classes of interfaces; the most complex are those integrating ROSE with combat simulation that employs planning algorithms. The authors have also identified several problems that modelers will face in amplifying the integration of logistics and combat models. For example, the representations of combat and logistics must be compatible in several dimensions that range from the treatment of reception and onward movement to the definition of sustainment policies. Alone, the ROSE model can be used to address important problems; when linked to combat simulation it can become even more useful. Balancing combat and support is just one of many potential applications.

Levine, Arnold, and Jeff Luck, *The New Management Paradigm: A Review of Principles and Practices*, RAND, Santa Monica, CA, MR-458-AF, 1994.

In the last 20 years, a new management paradigm has emerged that is the antithesis of mass production. The authors find that this paradigm has two underlying principles: (1) customer satisfaction is central to the firm's prosperity, and (2) the firm is a system of interdependent processes that develops the products and services customers purchase. The authors describe in detail the management practices resulting from these principles. For example, firms using this paradigm integrate marketing, research and development, engineering, design, production, and distribution. They delegate greater operational responsibility to those who design and manufacture the product. To respond quickly to shifting demand, they produce small lot sizes with minimal setup times. And they work with fewer, more qualified suppliers, involving them in every phase of production. The success of new business practices depends upon the initiative of top management, which must establish a philosophical groundwork for implementing new practices, and decide whether the change will be radical and immediate or incremental and cumulative.

Matejek, Joe, presentation at Executive Forum on Changing the Department of Defense Enterprise, George Mason University, Fairfax, VA, August 9-10, 1994.

Moore, Nancy, John Halliday, K. M. Beam, Doug McIver, Matthew Lewis, Fred Finnegan, and T. Masselink, "Materiel Distribution: Improving Support to Army Operations in Peace and War," RAND, Santa Monica, CA, unpublished draft.

This draft describes the Arroyo Center's study on materiel distribution, presents some initial results, outlines some current activities, and discusses some next steps. In terms of initial results, the draft argues that the Army distribution is complex and compartmented, that it is slow, and that the problems affecting it are long-standing. The draft further argues that fixing it requires a systemic approach, since past stovepipe approaches have not worked. The draft points out that industry has met and overcome many of the challenges confronting DoD by combining technology with reorganization and by establishing high-performance standards to increase performance and productivity, and argues that this approach is a useful model for DoD to explore. It concludes that now is the time to rethink how to provide distribution support to the Army. The draft then discusses current activities and next steps in the project.

Office of the Secretary of Defense, *Defense Business Operations Fund FY 1994 Budget Estimates Corporate Overview Operating Budgets, Volume II*, Washington, DC, 1993.

Office of the Secretary of Defense, Economic Security, *Report on the Performance of Department of Defense Commercial Activities: Fiscal Year 1994*, Washington, DC, January 30, 1995, p. 4.

Ostroff, Frank, and Douglas Smith, "The Horizontal Organization," *The McKinsey Quarterly*, No. 1, 1992, pp. 148-167.

Pohlen, Terrance L., and Bernard J. LaLonde, "Implementing Activity-Based Costing (ABC) in Logistics," *Journal of Business Logistics*, Council of Logistics Management, Vol. 15, No. 2, 1994, pp. 1-23.

Prahalad, C. K., and Gary Hamel, "The Core Competence of the Corporation," *Harvard Business Review*, May-June 1990.

Pyles, Ray, and Hy Shulman, *United States Air Force Fighter Support in Operation Desert Storm*, RAND, Santa Monica, CA, MR-468-AF, 1995.

Quinn, James, and Frederick Hilmer, "Strategic Outsourcing," *Sloan Management Review*, Vol. 35, No. 4, Summer 1994.

Robbins, Marc, "Resupply in Force-Projection Operations: Evidence from Restore Hope, Desert Shield/Storm, and Just Cause," an unpublished RAND annotated briefing.

This draft examines the ability of the current DoD distribution system, and its Army component, to move high-priority items rapidly to the customer. The author uses recent operations in central America, Southwest Asia, and the Horn of Africa as examples of force-projection missions in which strategic resupply was critical for theater support. In these operations, the standard distribution system showed limited ability to discriminate among the priorities of needed items, with the lowest priority item sometimes moving just as quickly, or more quickly, as the highest priority item. In each mission, "side channels," either ad hoc, created specifically for that operation, or serving just part of the deployed forces, were far more effective in responding quickly to theater needs. The author concludes that: (1) a future system should retain selected aspects of each of these side channels, emphasizing rapid in-theater monitoring of critical requisitions and direct communications between representatives of the National Inventory Control Point (NICP) in the theater and in CONUS; and (2) the system needs a way of communicating these high priorities between the NICP and the non-Army supply depots and airports of embarkation.

Robbins, Marc, "The Need to Measure Repair Cycle Time: Performance Measurement in the Army's Velocity Management Initiative," RAND, Santa Monica, CA, unpublished draft.

Robbins, Marc, and Doug McIver, *Precision-Guided Logistics: Flexible Support for the Force-Projection Army's High-Technology Weapons*, RAND, Santa Monica, CA, MR-437-A, 1994.

Drawing on the Army's experience in Operation Just Cause (OJC), Operation Desert Shield (ODS), and Operation Desert Storm (ODSt), this study explores "what if" scenarios for the three operations to examine how well the Army could have supported its new high-technology weapon systems in the face of different stresses. Although the logistics support for all three operations was a success, the "what if" analysis suggests that the forces were vulnerable to risks in the nature of the contingencies; for example, an extended OJC would have severely affected weapon system sustainability, as would have been the case if fighting had erupted early in ODS or if operating tempos were higher than they were in ODS. To reduce the risks inherent in these uncertainties, the draft argues for a more flexible support concept that tailors support packages to the specific needs of different types of contingencies. The research suggests that such a system could help maintain high weapon system availability across the range of contingency uncertainty and could do so at a cost no greater, and almost certainly less, than that of the current structure.

Robbins, Marc, Mort Berman, Doug McIver, William Mooz, and John Schank, *Developing Robust Support Structures for High-Technology Subsystems: The AH-64 Apache Helicopter*, RAND, Santa Monica, CA, R-3768-A, 1991.

Using data on the high-technology subsystems of the AH-64 Apache attack helicopter, this report hypothesizes five alternative logistics structures (two traditional ones that rely on conventional depot support of intermediate repair and three that focus on more responsive support) and evaluates them in terms of comparative cost-effectiveness and robustness. The study found that the responsive support alternatives featuring Special Repair Activity (SRA) support of critical items or fast-turnaround continental U.S. (CONUS) depots tied to the theater by assured rapid transportation offer a means for providing cost-effective support of the Apache in a variety of conditions. The research substantiates previous RAND research on the M-1 tank that argued that the Army must increase the responsiveness in its logistics structures or face a loss in combat capability. (See also R-3673, R-3793.)

Ross, Randy, *Government and Private Sector: Who Should Do What?*
New York: Crane Russak & Company, 1988.

Senge, Peter M., *The Fifth Discipline: The Art and Practice of the Learning Organization*, New York: Doubleday, 1990.

Setear, John K., Carl Builder, Melinda Baccus, and E. W. Madewell, *The Army in a Changing World: The Role of Organizational Vision*, RAND, Santa Monica, CA, R-3882-A, 1990.

This report is about the Army's future and the role an organizational vision for the Army can play in that future. The authors suggest that for an Army that wishes to adapt to the changing national security planning environment, the key element is the Army's vision of itself, its sense of identity and purpose, of what it is and what it is about. While the Army's essential institutional planning problem over the past 40 years has largely been one of managing budget, personnel, and technological resources, the problem for the future may involve reconceiving the Army to meet new threats to the nation's security or to minimize institutional damage. Although the Army has no explicitly acknowledged current organizational vision, its institutional thoughts and actions do reflect a widely shared sense of identity and purpose as the ready armored defender of Central Europe. If the authors' projections of planning trends materialize, this current vision puts the Army on a collision course with what is perceived as its post-Cold War future. A fundamental choice may have to be made between the Army's current combat role and its former historical role as a provider of noncombat military services to the nation. Of the eight alternative visions of the Army that the authors pose, they believe the most relevant and realistic ones call for a U.S.-based Army performing general military service that may rely on either active or reserve forces. 83 pp.

Slay, F. Michael, and Crain C. Sherbrooke, *The Nature of the Aircraft Component Failure Process: A Working Note*, Logistics Management Institute, Bethesda, MD, IR701R1, February 1988.

Stalk, George, Jr., "Time--the Next Source of Competitive Advantage," *Harvard Business Review*, July-August 1988, pp. 41-51.

Sweeney, Col. Bruce D., "Dual-Use Technology...The Precision Lightweight GPS Receiver," *Army Research, Development and Acquisition Bulletin*, November-December 1993, pp. 38-41.

Tapscott, Don, and Art Caston, *Paradigm Shift*, New York: McGraw-Hill, 1993.

Vick, James L., "DDCO Process to Delight Its Customers," briefing given at the Defense Distribution Depot, Columbus, OH, October 14, 1994.

Weissenborn, Henry M., "Take the EDI 'Express Train' from Requisitioner to Strategic Supplier," *Proceedings*, Council of Logistics Management Annual Conference, San Antonio, TX, October 11-14, 1992.

Womack, James T., Daniel T. Jones, and Daniel Roos, *The Machine That Changed the World: The Story of Lean Production*, New York: Macmillan, 1990.